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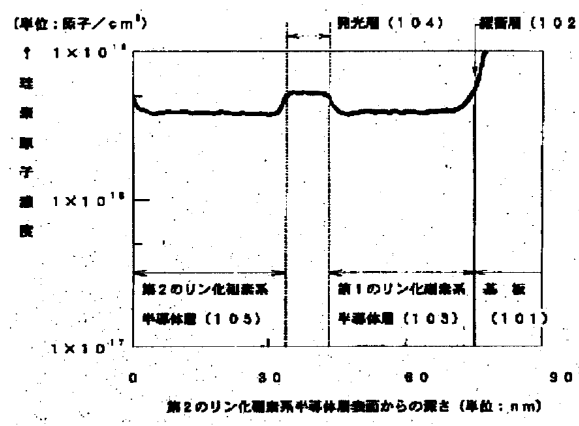
(54)【発明の名称】　ｐｎ接合型リン化硼素系半導体発光素子およびその製造方法

(57)【要約】
【課題】リン化硼素系半導体発光素子において、発光層からの第ＩＶ族元素の外部拡散を抑制し、発光層内の第ＩＶ族元素の原子濃度を発光強度の観点から最適な濃度に維持する。
【解決手段】第１のリン化硼素系半導体層と第ＩＶ族元素を故意に添加したＩＩＩ－Ｖ族半導体層からなる発光層と第２のリン化硼素系半導体層とからなるｐｎ接合型ヘテロ（異種）接合構造を備えたリン化硼素系半導体発光素子に於いて、第１のリン化硼素系半導体層を、第ＩＶ族元素を含むアンドープの第１の伝導形のリン化硼素系半導体から構成し、第２のリン化硼素系半導体層を、第ＩＶ族元素を含む第２の伝導形のリン化硼素系半導体層から構成する。



【特許請求の範囲】

【請求項１】第１の伝導形の珪素（Ｓｉ）単結晶からなる基板と、該基板上に設けられた第１の伝導形の第１のリン化硼素系半導体層と、第１のリン化硼素系半導体層上に設けられた、第１または第２の伝導形を有する、元素周期律表上の第ＩＶ族元素を故意に添加したＩＩＩ－Ｖ族半導体層からなる発光層と、発光層上に設けられた第２の伝導形の第２のリン化硼素系半導体層とを有し、第１のリン化硼素系半導体層と発光層と第２のリン化硼素系半導体層とからなるｐｎ接合型ヘテロ（異種）接合構造を備えたｐｎ接合型リン化硼素系半導体発光素子に於いて、第１のリン化硼素系半導体層を、第ＩＶ族元素を含むアンドープの第１の伝導形のリン化硼素系半導体から構成し、第２のリン化硼素系半導体層を第ＩＶ族元素を含む、第１の伝導形とは反対の第２の伝導形のリン化硼素系半導体層から構成したことを特徴とするｐｎ接合型リン化硼素系半導体発光素子。

【請求項２】第１のリン化硼素系半導体層には、発光層に含まれるものと同一種の第ＩＶ族元素が含まれていることを特徴とする請求項１に記載のｐｎ接合型リン化硼素系半導体発光素子。

【請求項３】第１のリン化硼素系半導体層に含まれる第ＩＶ族元素の原子濃度を、発光層の内部の第ＩＶ族元素の原子濃度に対して±３０％以内としたことを特徴とする請求項１または２に記載のｐｎ接合型リン化硼素系半導体発光素子。

【請求項４】第１のリン化硼素系半導体層及び発光層に含まれる第ＩＶ族元素を珪素（Ｓｉ）としたことを特徴とする請求項１乃至３の何れか１項に記載のｐｎ接合型リン化硼素系半導体発光素子。

【請求項５】第２のリン化硼素系半導体層を、アンドープの第２の伝導形のリン化硼素系半導体層から構成したことを特徴とする請求項１乃至４の何れか１項に記載のｐｎ接合型リン化硼素系半導体発光素子。

【請求項６】第２のリン化硼素系半導体層を、第ＩＶ族元素を故意に添加した第２の伝導形のリン化硼素系半導体層から構成したことを特徴とする請求項１乃至４の何れか１項に記載のｐｎ接合型リン化硼素系半導体発光素子。

【請求項７】第２のリン化硼素系半導体層には、発光層に添加したと同一種の第ＩＶ族元素が含まれていることを特徴とする請求項１乃至６の何れか１項に記載のｐｎ接合型リン化硼素系半導体発光素子。

【請求項８】第２のリン化硼素系半導体層に含まれる第ＩＶ族元素の原子濃度を、発光層の内部の第ＩＶ族元素の原子濃度に対して±３０％以内としたことを特徴とする請求項１乃至７の何れか１項に記載のｐｎ接合型リン化硼素系半導体発光素子。

【請求項９】第２のリン化硼素系半導体層及び発光層に含まれる第ＩＶ族元素を珪素（Ｓｉ）とした、ことを特徴とする請求項１乃至８の何れか１項に記載のｐｎ接合型リン化硼素系半導体発光素子。

【請求項１０】第１のリン化硼素系半導体層に含まれる珪素の原子濃度を、硼素空孔を占有するリン原子の濃度、またはリン空孔を占有する硼素原子の濃度の何れの濃度以下としたことを特徴とする請求項４に記載のｐｎ接合型リン化硼素系半導体発光素子。

【請求項１１】第２のリン化硼素系半導体層に含まれる珪素の原子濃度を、硼素空孔を占有するリン原子の濃度、またはリン空孔を占有する硼素原子の濃度の何れの濃度以下としたことを特徴とする請求項９に記載のｐｎ接合型リン化硼素系半導体発光素子。

【請求項１２】ＭＯＣＶＤ法により、ｐ型のリン化硼素系半導体層を１０００～１２００℃の温度で、またｎ型のリン化硼素系半導体層を７５０～９５０℃の温度で形成することを特徴とする請求項１乃至１１に記載のｐｎ接合型リン化硼素系半導体発光素子の製造方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、ヘテロ接合構造を備えたリン化硼素系半導体素子を構成するための技術に係り、特に高い発光強度を呈するリン化硼素系半導体発光素子を得るための技術に関する。

【０００２】

【従来の技術】従来にあって、ＩＩＩ－Ｖ族化合物半導体の一種として、リン化硼素（ＢＰ）が知られている（Ｎａｔｕｒｅ、１７９、Ｎｏ．４５６９（１９５７）、１０７５頁参照）。また、リン化硼素（ＢＰ）は間接遷移型の半導体であるため（寺本　巌著、「半導体デバイス概論」（１９９５年3月３０日、（株）培風館発行初版）、２８頁参照）、半導体発光素子の発光層を形成するには好適な材料とはならないとされている。このため、従来のリン化硼素系半導体層を備えてなるリン化硼素系半導体発光ダイオード（ＬＥＤ）では、リン化硼素等のリン化硼素系半導体層は、もっぱら、珪素単結晶（シリコン）からなる基板上に設けられる緩衝層を構成するに用いられている（米国特許６、０６９、０２１号参照）。また、レーザダイオード（ＬＤ）では、例えば、オーミック（Ｏｈｍｉｃ）電極を設けるためのコンタクト（ｃｏｎｔａｃｔ）層として利用されている（特開平２－２８８３８８号公報参照）。

【０００３】一方、半導体発光素子にあって、発光層は、間接遷移型に比較して放射再結合効率に優れる直接遷移型の半導体材料から構成するのが通常である。リン化硼素系半導体ＬＥＤでは、従来より発光層は、主に、窒化ガリウム・インジウム（$Ga_XIn_{1-X}N$：$0 \leqq X \leqq 1$）から構成されている（特公昭５５－３８３４号公報参照）。特に、珪素（Ｓｉ）、ゲルマニウム（Ｇｅ）等の元素周期律表に掲載される第ＩＶ族元素を故意に添加した$Ga_XIn_{1-X}N$（$0 \leqq X \leqq 1$）から発光層を構成す

るのが通例となっている（特開平６－２６０６８０号公報参照）。第ＩＶ族元素のドーピング（ｄｏｐｉｎｇ）により、高い強度の発光をもたらす$Ga_{X}In_{1-X}N$（$0 \leq X \leq 1$）発光層を提供できるとされるからである（日本国特許第２５６０９６３号公報参照）。半導体発光素子にあって、高強度の発光を得るために、発光部は、発光層と、発光層を挟持するｐ形またはｎ形の障壁（クラッド）層とから構成されるｐｎ接合型の２重異種（ｄｏｕｂｌｅ　ｈｅｔｅｒｏ：ＤＨ）構造とするのが通常である（特開平６－２６０２８３号公報参照）。

【０００４】従来に於いて、ｐ形のリン化硼素系半導体層は、元素周期律の第ＩＩ族に属するマグネシウム（Ｍｇ）や亜鉛（Ｚｎ）等を故意に添加して（ドーピングして）得るのが通常である（①特開平２－２７５６８２号、②特開平２－２８８３７１号公報、③特開平２－２８８３８８号公報、③特開平１０－２４２５１４号公報、④特開平１０－２４２５１５号公報、及び⑤特開平１０－２４２５６７号公報参照）。また、ｎ形のリン化硼素系半導体層は珪素（Ｓｉ）等の第ＩＶ族元素のドーピングに依り得るのが通常となっている（例えば、上記の特開平２－２８８３８８号公報参照）。この様な従来技術例に鑑み、ｐｎ接合型ＤＨ構造の発光部をなすｐ形障壁層は、Ｍｇ或いはＺｎ等をドーピングしたｐ形リン化硼素系半導体層から構成されるものとなっている。また、ｎ形障壁層は珪素をドーピングしたｎ形リン化硼素系半導体層から構成されるものとなっている（特願２００１－１５８２８２号参照）。

【０００５】一方で、第ＩＶ族元素である珪素（Ｓｉ）は、リン化硼素系半導体に対して、他のＩＩＩ－Ｖ族化合物半導体に対する場合と同様に、両性不純物（ａｍｐｈｏｔｅｒｉｃ　ｉｍｐｕｒｉｔｙ）として働くと指摘されている（庄野　克房著、「半導体技術（上）」（１９９２年6月２５日、（財）東京大学出版会発行９刷）、７７頁参照）。また、リン化硼素半導体層については、不純物を故意に添加しない、所謂、アンドープ（ｕｎｄｏｐｅ）の状態で、リン化硼素層の気相成長温度を適宜、選択することによりｎ形またはｐ形の半導体層を得る技術も開示されている（上記の「半導体技術（上）、７６～７７頁参照）。アンドープのリン化硼素半導体層の伝導形の決定には、硼素空孔とリン空孔との存在が関与しているとされる（庄野　克房著、「超ＬＳＩ時代の半導体技術１００集〔ＩＩＩ〕」（昭和５７年4月1日、（株）オーム社発行、「電子雑誌エレクトロニクス」、第２７巻第４号付録、８６～８７頁参照）。

【０００６】

【発明が解決しようとする課題】にも拘わらず、従来技術では、伝導形を相違するリン化硼素系半導体層を、わざわざ、異なる種類の不純物（ｄｏｐａｎｔ）をドーピングして得ていた。リン化硼素系半導体層からなるｐｎ接合構造を得るにあたっての問題点は、伝導形に依って、わざわざドーパント種を変更してｎ形またはｐ形のリン化硼素系半導体層を得なければならない煩雑さにあった。また、この煩雑なドーピング操作を回避するため、縦しんば、アンドープのリン化硼素系半導体層を障壁層として利用して、例えば、ｐｎ接合型のＤＨ構造の発光部を得ようと試みても、発光層にドーピングした第ＩＶ族元素がアンドープのリン化硼素系半導体障壁層へ拡散するのを充分に抑制するに至っていない。また、上記の如く高強度の発光をもたらすためにドーピングした第ＩＶ族元素、例えば、珪素がアンドープのリン化硼素半導体層へ拡散する程度が変動するため、発光層から出射される発光の強度は不安定となり、しいては、安定した発光強度を呈すリン化硼素系半導発光素子を得るに至ってはいない。

【０００７】例えば、第ＩＶ族元素を不純物としてドーピングしてなる半導体層を発光層とするｐｎ接合型ＤＨ構造のリン化硼素系半導体発光素子にあって、簡便に形成できるアンドープのリン化硼素系半導体層への第ＩＶ族元素の拡散を抑制でき、従って、高発光強度をもたらすために好適な濃度に添加された発光層の内部の第ＩＶ族元素の濃度の減少を回避できる構成が提供されれば、安定して高い発光強度を呈するリン化硼素系半導体発光素子を得るに有効となる。本発明では、特に、高発光強度のリン化硼素系半導体発光素子をもたらすに効果を奏するヘテロ接合構造の発光部の構成を提示するものである。

【０００８】

【課題を解決するための手段】即ち、本発明は、

（１）第１の伝導形の珪素（Ｓｉ）単結晶からなる基板と、該基板上に設けられた第１の伝導形の第１のリン化硼素系半導体層と、第１のリン化硼素系半導体層上に設けられた、第１または第２の伝導形を有する、元素周期律表上の第ＩＶ族元素を故意に添加したＩＩＩ－Ｖ族半導体層からなる発光層と、発光層上に設けられた第２の伝導形の第２のリン化硼素系半導体層とを有し、第１のリン化硼素系半導体層と発光層と第２のリン化硼素系半導体層とからなるｐｎ接合型ヘテロ（異種）接合構造を備えたリン化硼素系半導体発光素子に於いて、第１のリン化硼素系半導体層を、第ＩＶ族元素を含むアンドープの第１の伝導形のリン化硼素系半導体から構成し、第２のリン化硼素系半導体層を第ＩＶ族元素を含む、第１の伝導形とは反対の第２の伝導形のリン化硼素系半導体層から構成したことを特徴とするｐｎ接合型リン化硼素系半導体発光素子。

（２）第１のリン化硼素系半導体層には、発光層に含まれるものと同一種の第ＩＶ族元素が含まれていることを特徴とする上記（１）に記載のｐｎ接合型リン化硼素系半導体発光素子。

（３）第１のリン化硼素系半導体層に含まれる第ＩＶ族元素の原子濃度を、発光層の内部の第ＩＶ族元素の原子

濃度に対して±３０％以内としたことを特徴とする上記（1）または（2）に記載のｐｎ接合型リン化硼素系半導体発光素子。

（4）第1のリン化硼素系半導体層及び発光層に含まれる第ＩＶ族元素を珪素（Ｓｉ）としたことを特徴とする上記（1）乃至（3）の何れか1項に記載のｐｎ接合型リン化硼素系半導体発光素子。

（5）第2のリン化硼素系半導体層を、アンドープの第２の伝導形のリン化硼素系半導体層から構成したことを特徴とする上記（1）乃至（4）の何れか1項に記載のｐｎ接合型リン化硼素系半導体発光素子。

（6）第2のリン化硼素系半導体層を、第ＩＶ族元素を故意に添加した第２の伝導形のリン化硼素系半導体層から構成したことを特徴とする上記（1）乃至（4）の何れか1項に記載のｐｎ接合型リン化硼素系半導体発光素子。

（7）第2のリン化硼素系半導体層には、発光層に添加したと同一種の第ＩＶ族元素が含まれていることを特徴とする上記（1）乃至（6）の何れか1項に記載のｐｎ接合型リン化硼素系半導体発光素子。

（8）第2のリン化硼素系半導体層に含まれる第ＩＶ族元素の原子濃度を、発光層の内部の第ＩＶ族元素の原子濃度に対して±３０％以内としたことを特徴とする上記（1）乃至（7）の何れか1項に記載のｐｎ接合型リン化硼素系半導体発光素子。

（9）第2のリン化硼素系半導体層及び発光層に含まれる第ＩＶ族元素を珪素（Ｓｉ）とした、ことを特徴とする上記（1）乃至（8）の何れか1項に記載のｐｎ接合型リン化硼素系半導体発光素子。

（10）第1のリン化硼素系半導体層に含まれる珪素の原子濃度を、硼素空孔を占有するリン原子の濃度、またはリン空孔を占有する硼素原子の濃度の何れの濃度以下としたことを特徴とする上記（4）に記載のｐｎ接合型リン化硼素系半導体発光素子。

（11）第2のリン化硼素系半導体層に含まれる珪素の原子濃度を、硼素空孔を占有するリン原子の濃度、またはリン空孔を占有する硼素原子の濃度の何れの濃度以下とした、ことを特徴とする上記（9）に記載のｐｎ接合型リン化硼素系半導体発光素子。である。また、本発明は、

（12）ＭＯＣＶＤ法により、ｐ型のリン化硼素系半導体層を１０００～１２００℃の温度で、またｎ型のリン化硼素系半導体層を７５０～９５０℃の温度で形成することを特徴とする上記（1）乃至（11）に記載のｐｎ接合型リン化硼素系半導体発光素子の製造方法。である。

【０００９】

【発明の実施の形態】本発明の第1の実施形態に於いて、基板には、｛１００｝、｛１１０｝、或いは｛１１１｝結晶面を表面とする｛１００｝－、｛１１０｝－、

｛１１１｝－珪素（Ｓｉ）単結晶を利用できる。また例えば、｛１１１｝結晶面より角度にして数度、傾斜した結晶面を表面とする珪素単結晶も基板として利用できる。特に、ダイヤモンド（ｄｉａｍｏｎｄ）結晶構造型の珪素単結晶の｛１１１｝結晶面には、｛１００｝結晶面等に比較して、珪素原子がより高い密度で存在している。このため、｛１１１｝－Ｓｉ単結晶は、上層のリン化硼素系半導体層を構成する硼素（Ｂ）原子及びリン（Ｐ）原子がＳｉ単結晶基板の内部へ侵入または拡散するのを防止するに有効な基板となる。珪素単結晶の伝導形は、ｎ形またはｐ形の何れでも構わない。基板をなす珪素単結晶の伝導形を、本発明では第1の伝導形と仮称する。導電性の珪素単結晶を基板とすれば、基板の裏面に正負、何れかの極性のオーミック（Ｏｈｍｉｃ）性電極を裏面電極として敷設でき、簡便に発光素子を構成するに寄与できる。特に、抵抗率を１ミリオーム（ｍΩ）以下、より望ましくは０．１ｍΩ以下とする低い比抵抗（抵抗率）の導電性単結晶基板は、順方向電圧（所謂、Ｖｆ）の低いＬＥＤをもたらすに貢献する。また、放熱性に優れるため、安定した発振をもたらすＬＤを構成するに有効となる。

【００１０】珪素単結晶基板表面上に積層する第1のリン化硼素系化合物半導体層は、硼素（Ｂ）とリン（Ｐ）とを構成元素として含む例えば、$B_{\alpha}Al_{\beta}Ga_{\gamma}In_{1-\alpha-\beta-\gamma}P_{1-\delta}As_{\delta}$（$0<\alpha\leqq 1$、$0\leqq\beta<1$、$0\leqq\gamma<1$、$0<\alpha+\beta+\gamma\leqq 1$、$0\leqq\delta<1$）から構成する。また、例えば、$B_{\alpha}Al_{\beta}Ga_{\gamma}In_{1-\alpha-\beta-\gamma}P_{1-\delta}N_{\delta}$（$0<\alpha\leqq 1$、$0\leqq\beta<1$、$0\leqq\gamma<1$、$0<\alpha+\beta+\gamma\leqq 1$、$0\leqq\delta<1$）から構成できる。第1のリン化硼素系半導体層とは、後述の第2のリン化硼素系半導体層よりも位置的に珪素単結晶基板の表面により近接して設ける半導体層である。また、その第1のリン化硼素系半導体層の伝導形は、基板をなす珪素単結晶の伝導形に一致する第1の伝導形とする。例えば、ｐ形の｛１１１｝－Ｓｉ単結晶基板上には、高抵抗のｐ形リン化硼素系半導体層を設ける場合を例示できる。

【００１１】第1のリン化硼素系化合物半導体層は特に、硼素（Ｂ）の組成（＝α）及びリン（Ｐ）の組成（＝１－δ）を何れも０．５（＝５０％）以上とする硼素及びリンを主体として含む例えば、$B_{\alpha}Al_{\beta}Ga_{\gamma}In_{1-\alpha-\beta-\gamma}P_{1-\delta}As_{\delta}$（$0.5\leqq\alpha\leqq 1$、$0\leqq\beta<0.5$、$0\leqq\gamma<0.5$、$0.5<\alpha+\beta+\gamma\leqq 1$、$0\leqq\delta<0.5$）、または$B_{\alpha}Al_{\beta}Ga_{\gamma}In_{1-\alpha-\beta-\gamma}P_{1-\delta}N_{\delta}$（$0.5\leqq\alpha\leqq 1$、$0\leqq\beta<0.5$、$0\leqq\gamma<0.5$、$0.5<\alpha+\beta+\gamma\leqq 1$、$0\leqq\delta<0.5$）から好適に構成できる。硼素（Ｂ）及びリン（Ｐ）の組成を各々、０．５以上とする硼素とリンとを主体的に含むリン化硼素系半導体混晶からは、伝導形を制御する不純物を故意に添加（＝ドーピング）せずとも第1或いは第2の伝導形の導電性のリン化硼素系半導体

層がもたらされる利点がある。即ち、アンドープで第１の伝導形のリン化硼素系半導体層を形成できるため、第１の伝導形のリン化硼素系半導体層を形成するに伝導形に依って添加する不純物種を変化させる煩雑性を回避できる。

【００１２】基板の珪素単結晶と同一の第１の伝導形を有する第１のリン化硼素系半導体層を、第ＩＶ族元素を含むアンドープ層から構成すると、不純物をドーピングする煩雑な操作から解放されると共に、放射される発光の強度を増加させるために発光層内にドーピングした第ＩＶ族元素の第１のリン化硼素系半導体層内への侵入、拡散を抑制するに効果が奏される。第１のリン化硼素系半導体層に含まれる第ＩＶ族元素は必ずしも１種類に限定する必要はない。第１の伝導形の第１のリン化硼素系半導体層に含有させる第ＩＶ族元素には、炭素（Ｃ）、珪素（Ｓｉ）、ゲルマニウム（Ｇｅ）、錫（Ｓｎ）等を例示できる。これらの第ＩＶ族元素にあって、炭素（Ｃ）や珪素（Ｓｉ）は、リン化硼素系半導体層等のＩＩＩ－Ｖ族化合物半導体内で顕著に拡散しないため、特に好適である。また特に、第１のリン化硼素系半導体層に含ませる第ＩＶ族元素を、発光層にドーピングした第ＩＶ族元素と同一とすれば、発光層の第ＩＶ族元素の第１のリン化硼素系半導体層への侵入、拡散を抑制するに効果を上げられる。本発明の第２の実施形態の例として、珪素ドープ発光層について、珪素を含ませた第１のリン化硼素系半導体層を設ける場合がある。また、炭素を含む第１のリン化硼素系半導体層上に炭素ドープ発光層を設ける例を挙げられる。

【００１３】炭素（Ｃ）や珪素（Ｓｉ）を含む第１の伝導形の第１のリン化硼素系半導体層は、これらの第ＩＶ族元素を故意に添加せずとも形成できる利点がある。例えば、珪素を含む第１のリン化硼素系半導体層は、珪素単結晶を基板とすることで簡便に得られる。７５０℃～１２００℃の温度、特に、８５０℃以上で１２００℃以下の温度に珪素単結晶基板を保持すると、珪素単結晶から遊離した珪素が好都合に第１のリン化硼素系半導体層の内部に混入することとなり、珪素を含む第１のリン化硼素系半導体層を形成できる。また、第１のリン化硼素系半導体層を成膜するにあたり、炭素（Ｃ）を含む官能基（ｆｕｎｃｔｉｏｎ　ｇｒｏｕｐ）、特に側鎖状或いは直鎖状の飽和または不飽和脂肪族官能基を付加した有機硼素化合物を硼素（Ｂ）源とすれば、炭素を含有する第１のリン化硼素系半導体層を簡易に形成できる。即ち、例えばメタン（CH_4）、トリメチル砒素（$(CH_3)_3As$）、四塩化炭素（CCl_4）や四臭化炭素（CBr_4）等の炭素含有化合物を炭素のドーパントとして改めて用いなくとも、例えば、トリメチル硼素（$(CH_3)_3B$）やトリエチル硼素（$(C_2H_5)_3B$）等のアルキル（ａｌｋｙｌ）硼素化合物の熱分解に因り発生する炭素を利用すれば、炭素を含む第１のリン化硼素系半導体層を簡便にして形成できる。換言すれば、これらのアルキル硼素化合物を硼素源とする有機金属化学的堆積法（ＭＯＣＶＤ法）等の気相成長手段により簡便に形成できる。

【００１４】第１の伝導形の第１のリン化硼素系半導体層に含ませる珪素（Ｓｉ）或いは炭素（Ｃ）等の第ＩＶ族元素の原子濃度は、発光層に含まれる第ＩＶ族元素の原子濃度の約０．５倍以上で約２倍以下とするのが好ましい。第１のリン化硼素系半導体層内の第ＩＶ族元素の原子濃度が、発光層のそれの約２倍を越える高濃度となると、第１のリン化硼素系半導体層から発光層への第ＩＶ族元素の拡散が生じ、発光層内の第ＩＶ族元素の原子濃度が徒に高濃度となる不都合を来す。逆に、発光層内の第ＩＶ族元素の原子濃度の約０．５倍未満の低濃度に第ＩＶ族元素を含む第１のリン化硼素系半導体層では、発光層より第１のリン化硼素系半導体層の内部へ向けての第ＩＶ族元素の拡散が顕著に発生する、このため、発光層内部の第ＩＶ族元素の原子濃度が減少し、高強度の発光をもたらすに不都合を生ずる。第１のリン化硼素系半導体層内の第ＩＶ族元素の合計の原子濃度として更に好適なのは、発光層内の第ＩＶ族元素の原子濃度と略均等である場合、即ち、発光層内の第ＩＶ族元素の原子濃度に対して±３０％の範囲内にある原子濃度である。発光層とリン化硼素系半導体層との第ＩＶ族元素の原子濃度の差異が小であるほど、その原子濃度の差に起因して発生する第ＩＶ族元素の相互拡散はより抑制され得る。最も好適なのは、第１のリン化硼素系半導体層の第ＩＶ族元素の原子濃度が、発光層のそれと同濃度である場合である。第１のリン化硼素系半導体層の内部の第ＩＶ族元素の原子濃度は、発光層の場合と同様に、例えば、２次イオン質量分析（ＳＩＭＳ）、オージェ（Ａｕｇｅｒ）電子分光分析法等の分析手段を利用して定量できる。

【００１５】本発明の第３の実施形態の一手段として、例えば、第ＩＶ族元素として珪素（Ｓｉ）を含む第１のリン化硼素系半導体層にあって、成膜温度を調整して、層内の珪素原子濃度を発光層のそれを基準にして±３０％以内とする例を上げられる。成膜温度、即ち、珪素単結晶基板の保持温度を高温とする程、また、高温に於ける保持時間を長くする程、層内の珪素原子濃度を高濃度とすることができる。例えば、成膜温度の１０５０℃に保持されたｐ形｛１１１｝－Ｓｉ単結晶基板上には、珪素原子濃度を約4×10^{17}原子／cm^3とするアンドープのｐ形リン化硼素（ＢＰ）層を形成することができる。成膜温度を１２００℃を越える高温とすると、菱面体結晶構造のB_6P或いは$B_{13}P_2$等の多量体のリン化硼素結晶が形成され易くなる。立方晶閃亜鉛鉱結晶型の第１のリン化硼素系半導体層内にリン化硼素多量体が発生すると、結晶型の相違に層内に因り発生した歪或いは結晶欠陥を介して珪素単結晶基板よりの珪素の層内への侵

入が顕著に生ずる。このため、第１のリン化硼素系半導体層内の珪素の原子濃度は時として、５×１０^{19} 原子／ｃｍ^{3} を越え、徒に高濃度となり、第１のリン化硼素系半導体層の結晶性は乱雑となる不都合を招く。

【００１６】また、珪素単結晶基板上で第１のリン化硼素系半導体層との中間に非晶質或いは多結晶の緩衝層を設けた場合、この様な結晶形態からなる緩衝層は、珪素単結晶基板と第１のリン化硼素系半導体層との格子ミスマッチを緩和すると共に、基板から拡散して来る珪素原子を捕獲する作用を有する。従って、第１のリン化硼素系半導体層内に於ける拡散して来た珪素原子の濃度は、珪素単結晶基板表面に直接、第１のリン化硼素系半導体層を接合させる場合に比べて、低く抑制され得る。緩衝層に捕獲される珪素原子は、緩衝層の層厚が厚い程、多量となる。即ち、第１のリン化硼素系半導体層の珪素原子濃度は、緩衝層の層厚を調節しても制御できる。珪素を含む第１のリン化硼素系半導体層にあって、層内の珪素の原子濃度は、硼素の空孔（ｖａｃａｎｃｙ）を占めるリン（Ｐ）原子、或いはリンの空孔を占有する硼素（Ｂ）原子の濃度未満とするのが好適である。この濃度の関係を維持することにより、縦しんば、珪素が両性不純物として働くと云えども、アンドープ状態で、ｎ形またはｐ形の双方の伝導形の半導体層を簡便に得ることが出来るリン化硼素系半導体の優位性を維持できる。

【００１７】第ＩＶ族元素として炭素（Ｃ）を含む第１のリン化硼素系半導体層にあっても、層内の炭素原子濃度は、成膜温度の調整に依り制御できる。成膜温度、即ち、珪素単結晶基板の保持温度を高温とする程、層内の炭素原子濃度を高濃度とすることができる。しかし、成膜温度を１２００℃を越える高温では、菱面体結晶構造のB_6P或いは$B_{13}P_2$等の多量体のリン化硼素結晶が形成され易くなり、組成的に均質なリン化硼素系半導体層を得るに不都合となる。また、第１のリン化硼素系半導体層内の炭素濃度は、硼素（Ｂ）源たる上記の有機硼素化合物の成膜環境内への供給する濃度を増加させる程、高濃度とすることができる。しかしながら、炭素を含む第１のリン化硼素系半導体層にあって、層内の炭素の原子濃度は、硼素の空孔（ｖａｃａｎｃｙ）を占めるリン（Ｐ）原子、或いはリンの空孔を占有する硼素（Ｂ）原子の濃度未満とするのが好適である。この濃度の関係を維持することにより、縦しんば、炭素が両性不純物として働くと云えども、アンドープ状態で帰結される第１の伝導形を維持できる。リン空孔を占有する硼素原子の濃度、或いは硼素空孔を占めるリン原子の濃度は各々、硼素－硼素（Ｂ－Ｂ）結合の濃度、或いはリン－リン（Ｐ－Ｐ）結合の濃度としてラマン（Ｒａｍａｎ）分光法、核磁気共鳴（ＮＭＲ）法等の手段に依り計測できる。

【００１８】本発明の第１の実施形態に係わるＩＩＩ－Ｖ族化合物半導体からなる発光層は、例えば、窒化ガリウム・インジウム（$Ga_XIn_{1-X}N$：$0≦X≦1$）や窒化リン化ガリウム（$GaN_{1-Y}P_Y$：$0≦Y≦1$）等のＩＩＩ族窒化物半導体層から構成できる。特に、例えば、第ＩＶ族元素を故意に添加（ｄｏｐｉｎｇ）したＩＩＩ族窒化物半導体層は発光層として好適に利用できる。発光層にドーピングする不純物には、珪素（Ｓｉ）、炭素（Ｃ）等を例示できる。特に珪素は、他の第ＩＶ族元素であるゲルマニウム（Ｇｅ）や錫（Ｓｎ）に比較して発光層の外部へ拡散し難い上に、炭素（Ｃ）の場合に比較してドーピングを容易に行えるため、好適に利用できる。発光層の内部の第ＩＶ族元素の好適な濃度は概ね、１×１０^{17} 原子／ｃｍ^{3}～１×１０^{19} 原子／ｃｍ^{3}である。特に、好適な約５×１０^{18} 原子／ｃｍ^{3}～約７×１０^{18} 原子／ｃｍ^{3}である。１×１０^{19} 原子／ｃｍ^{3}を越える様に第ＩＶ族元素をドーピングした発光層では、結晶性が悪化し、高強度の発光をもたらす発光層を得るに至らない。発光層の伝導形は第１または第２の伝導形とする。第２の伝導形の発光層の場合、第１の伝導形の第１のリン化硼素系半導体層との接合により、単一ヘテロ（ｓｉｎｇｌｅ ｈｅｔｅｒｏ：ＳＨ）接合型ｐｎ接合構造が構成できる。また、第１の伝導形の発光層に、後述する第２の伝導形の第２のリン化硼素系半導体層を接合させて設ける構成とすれば、発光層と第２のリン化硼素系半導体層とのｐｎ接合構造を含むダブルヘテロ（ｄｏｕｂｌｅ ｈｅｔｅｒｏ：英略称ＤＨ）構造の発光部を構築できる。本発明の第４の実施形態の一例として、第１のリン化硼素系半導体層を珪素を含むアンドープのリン化硼素・ガリウム（$B_XGa_{1-X}P$：０．５≦Ｘ≦１）層とし、珪素をドーピングして、珪素の原子濃度を２×１０^{17} 原子／ｃｍ^{3}とした窒化リン化ガリウム（$GaN_{1-Y}P_Y$：$0≦Y≦1$）から発光層を構成する場合を上げられる。

【００１９】発光層は、単一量子井戸構造（ＳＱＷ）または多重量子井戸構造（ＭＱＷ）から構成できる。キャリア（ｃａｒｒｉｅｒ）のトンネル（ｔｕｎｎｅｌ）効果を利用する量子井戸構造にあっては、井戸（ｗｅｌｌ）層よりは厚い障壁（ｂａｒｒｉｅｒ）層も薄膜から構成する必要がある。連続性のある薄膜から構成される量子井戸構造の発光層は、成膜以前に予め、硼素（Ｂ）とリン（Ｐ）とを含む被膜を内壁に被着させておいた成長炉を使用して、珪素単結晶基板上に成膜したリン化硼素系半導体層を下地として得られる。上記の被膜は、反応炉内壁或いは内壁に付着した分解生成物を起源とする珪素単結晶基板の表面を汚染する物質の放出を抑制して、表面の平坦性及び連続性に優れるリン化硼素系半導体層を得るに有効に作用し、しいては、表面の平坦性と連続性に優れる発光層を形成するに好都合となる。

【００２０】波長をλとする光を出射する発光層を、波長をλとする光に対し、３０％以上の反射率を有する層厚の第１のリン化硼素系半導体層上に設ける積層構成とすると、第１のリン化硼素系半導体層に依り、発光層か

らの一部の発光が反射されるため、例えば、素子外部への発光の取り出し効率に優れるＬＥＤを構成するに優位となる。例えば、波長を４２０ｎｍとする青紫光を発する発光層を、層厚を約３００ｎｍとする第１のリン化硼素半導体層上に設ける積層構成を例示できる。第１のリン化硼素系半導体層を単量体のリン化硼素（ＢＰ）から構成する場合、例えば、波長λ（単位ｎｍ；$420 \leqq \lambda \leqq 490$）の発光と、それに対し３０％以上の反射率を与えられる第１のリン化硼素系半導体層の層厚（単位：ｎｍ）との間には、次記の関係式（１）の関係がある。

$\lambda \fallingdotseq 0.135 \cdot d + 380$ ・・・関係式（１）

【００２１】本発明の第５の実施形態に於いては、上記の発光層上に設ける第２の伝導形の第２のリン化硼素系半導体層を、アンドープのリン化硼素系半導体層から構成する。第２のリン化硼素系半導体層は、第１のリン化硼素系半導体層の場合と同じく、例えば、$B_{\alpha}Al_{\beta}Ga_{\gamma}In_{1-\alpha-\beta-\gamma}P_{1-\delta}As_{\delta}$（$0<\alpha \leqq 1$、$0 \leqq \beta <1$、$0 \leqq \gamma <1$、$0<\alpha+\beta+\gamma \leqq 1$、$0 \leqq \delta <1$）から構成する。また、例えば、$B_{\alpha}Al_{\beta}Ga_{\gamma}In_{1-\alpha-\beta-\gamma}P_{1-\delta}N_{\delta}$（$0<\alpha \leqq 1$、$0 \leqq \beta <1$、$0 \leqq \gamma <1$、$0<\alpha+\beta+\gamma \leqq 1$、$0 \leqq \delta <1$）から構成できる。第２のリン化硼素系半導体層とは、発光層を挟んで、前述の第１のリン化硼素系半導体層に対向して設ける半導体層である。また、第１のリン化硼素系半導体層と発光層を挟持してｐｎ接合型ＤＨ構造の発光部を構成するための導電性の半導体層である。第２のリン化硼素系半導体層の伝導形は、基板をなす珪素単結晶及び第１のリン化硼素系半導体層とは逆とする。例えば、ｐ形の｛１１１｝－Ｓｉ単結晶及びｐ形の第１のリン化硼素系半導体層に対し、第２のリン化硼素系半導体層はｎ形層とする。

【００２２】特に、硼素（Ｂ）の組成（＝α）及びリン（Ｐ）の組成（＝１－δ）を何れも０．５（＝５０％）以上とする硼素及びリンを主体として含む例えば、$B_{\alpha}Al_{\beta}Ga_{\gamma}In_{1-\alpha-\beta-\gamma}P_{1-\delta}As_{\delta}$（$0.5 \leqq \alpha \leqq 1$、$0 \leqq \beta <0.5$、$0 \leqq \gamma <0.5$、$0.5<\alpha+\beta+\gamma \leqq 1$、$0 \leqq \delta <0.5$）、または$B_{\alpha}Al_{\beta}Ga_{\gamma}In_{1-\alpha-\beta-\gamma}P_{1-\delta}N_{\delta}$（$0.5 \leqq \alpha \leqq 1$、$0 \leqq \beta <0.5$、$0 \leqq \gamma <0.5$、$0.5<\alpha+\beta+\gamma \leqq 1$、$0 \leqq \delta <0.5$）から好適に構成できる。リン化硼素（Ｂ）とリン（Ｐ）とを主体的に含むリン化硼素系半導体混晶からは、伝導形を制御する不純物を故意に添加（＝ドーピング）せずとも第２の伝導形の導電性のリン化硼素系半導体層がもたらされる利点がある。即ち、アンドープで第２の伝導形のリン化硼素系半導体層を簡便に得られる利点がある。

【００２３】不純物種の変更を伴うドーピング操作を回避できると共に、第１及び第２のリン化硼素系半導体層をアンドープ層から構成することには、硼素（Ｂ）またはリン（Ｐ）の空孔に関与するドナー（ｄｏｎｏｒ）またはアクセプタ（ａｃｃｅｐｔｏｒ）成分の相対的な濃度比率を変更することにより、容易に高いキャリア濃度で低抵抗の導電層が得られる利点がある。例えば、アンドープであっても、キャリア濃度にして約5×10^{18} cm^{-3}を越える低抵抗のｎ形リン化硼素系半導体層を得ることができる。また、アンドープであれば、約1×10^{19} cm^{-3}を越えるキャリア濃度の低抵抗のｐ形リン化硼素系半導体層を簡便に構成できる。例えば、硫黄（Ｓ）或いはセレン（Ｓｅ）等の第ＶＩ族元素のｎ形不純物を多量にドーピングしたところで、上記のアンドープの場合の如くの高い電子濃度を安定して発現するのは難しく、却って、多量の不純物の添加により、表面は乱雑で且つ連続性に欠ける半導体層がもたらされるのみである。また、第ＩＩ族元素の亜鉛（Ｚｎ）、カドミウム（Ｃｄ）等の硼素（Ｂ）と化合物を形成し難いｐ形不純物性を多量にドーピングしたところで、上記の高い正孔濃度の低抵抗のリン化硼素系半導体層を安定して得るに至らない上に、乱雑な表面の不連続なる半導体層が帰結されるのみである。即ち、ｎ形またはｐ形の何れの伝導形のリン化硼素系半導体層を得る場合でも、不純物を故意に添加しないアンドープ手段に依るのが得策である。

【００２４】アンドープのリン化硼素系半導体層の伝導形は、成膜温度を調節して制御できる。ｎ形のアンドープリン化硼素系半導体層を得るに適する成膜温度は、大凡、７５０℃～９５０℃である。一方、アンドープのｐ形リン化硼素系半導体層を得るに適するのは、約１０００℃～約１２００℃である。特に、約１０２５℃～約１１００℃の範囲が好適である。約１０００℃を越える高温で成膜したリン化硼素系半導体層、特に、｛１１１｝－結晶面を双晶境界面とする双晶（ｔｗｉｎｎｉｎｇ）を含む単量体のリン化硼素（ｂｏｒｏｎ　ｍｏｎｏｐｈｏｓｐｈｉｄｅ）層は、第１または第２のリン化硼素系半導体層として好適に利用できる。層の内部に含まれる双晶は、例えば発光層との格子のミスミット（ｍｉｓｆｉｔ）等を緩和して結晶性に優れるリン化硼素系半導体層をもたらすに貢献できる。また、成膜反応系へ供給する硼素（Ｂ）等の第ＩＩＩ族の構成元素の合計の濃度に対する、リン（Ｐ）等の第Ｖ族構成元素の合計の濃度の比率、所謂、Ｖ／ＩＩＩ比率も伝導形の制御に影響を与える。成膜温度を同一とした場合、Ｖ／ＩＩＩ比率を高比率とする程、アンドープのｎ形リン化硼素系半導体層が得られ易くなる。

【００２５】本発明の第６の実施形態に於いては、第２のリン化硼素系半導体層を、第ＩＶ族元素を故意に添加した第２の伝導形のリン化硼素系半導体層から構成する。第２のリン化硼素系半導体層は、第１のリン化硼素系半導体層よりも珪素単結晶基板に対し、より遠隔な位置に配置されている。このため、第１のリン化硼素系半導体層の場合と比較して、基板の珪素単結晶を起源として拡散して来る珪素原子の濃度は減少する状況にある。

このため、第１のリン化硼素系半導体層の場合とは異なり、第２のリン化硼素系半導体層への第ＩＶ族元素の添加は、上記の好適な第ＩＶ族元素の原子濃度を得るに好都合な手段となる。添加する第ＩＶ族元素には、炭素（Ｃ）、珪素（Ｓｉ）、ゲルマニウム（Ｇｅ）、錫（Ｓｎ）を例示できる。炭素の添加源には、例えばメタン（CH_4）、トリメチルリン（$(CH_3)_3P$）や四臭化炭素（CBr_4）等の炭素含有化合物を例示できる。珪素のドーピング源には、シラン（SiH_4）やジシラン（Si_2H_6）等の珪素含有気体を例示できる。

【００２６】ｎ形またはｐ形不純物を添加しなくとも、アンドープ状態で既に、上記の如くの高キャリア濃度の導電層が得られているため、此処では、第ＩＶ族元素を第２のリン化硼素系半導体層の伝導形を制御する目的で添加するのでは無い。あくまでも、発光層に添加した第ＩＶ族元素の第２のリン化硼素系半導体層の内部への拡散を抑制して、発光層内の第ＩＶ族元素の原子濃度を高強度の発光をもたらすための濃度に維持するためである。第ＩＶ族元素は、第２のリン化硼素系半導体層の伝導形を支配する、硼素空孔を占めるリン原子、或いはリン空孔を占有する硼素原子の濃度以下とする。空孔が関与したドナー或いはアクセプタ成分の濃度を越えて多量に第ＩＶ族元素を添加しても、表面の平坦性が損なわれた第２のリン化硼素系半導体層が帰結されるのみである。

【００２７】本発明の第７の実施形態では、第２のリン化硼素系半導体層に含まれる第ＩＶ族元素と発光層に添加する第ＩＶ族不純物とを同一とする。発光層と第２のリン化硼素系半導体層とに存在させる第ＩＶ族元素を同一とすることにより、両層間に於ける第ＩＶ族元素の相互拡散を抑制できる。ましてや、両層に於ける第ＩＶ族元素の原子濃度を略同等とすれば、第ＩＶ族元素の発光層から第２のリン化硼素系半導体層への拡散、逆に、第２のリン化硼素系半導体層から発光層への拡散の双方を抑制するにより効果を上げられる。発光層及び第２のリン化硼素系半導体層共々、層内の第ＩＶ族元素の原子濃度は、第ＩＶ族元素のドーピング量をもって調節できる。第ＩＶ族元素の原子濃度の合わせるべき基準は、あくまでも、高強度の発光を得るべく選択された、発光層の第ＩＶ族元素の原子濃度である。第１若しくは第２のリン化硼素系半導体層の第ＩＶ族元素の原子濃度が発光層の最適な原子濃度に一致しない場合は、第１及び第２のリン化硼素系半導体層内の第ＩＶ族元素の原子濃度を発光層の最適な濃度を基準として±３０％以内に差異内に調整するのが望ましい。更には、第１及び第２のリン化硼素系半導体層の第ＩＶ族元素の原子濃度を、発光層のそれに合致させるのが、第ＩＶ族元素の相互拡散を抑制して、高強度の発光を与える発光層を得るに最も好都合となる。

【００２８】また、発光層と第２のリン化硼素系半導体層との間の第ＩＶ族元素の原子濃度の差異が大である程、発光層と第２のリン化硼素系半導体層との間の第ＩＶ族元素の拡散は顕著となる。従って、第２のリン化硼素系半導体層の第ＩＶ族元素の原子濃度は、発光層の第ＩＶ族元素の原子濃度と同一であるのが最適である。少なくとも、発光層の第ＩＶ族元素の濃度に対して±３０％の範囲にある原子濃度であるのが望ましい。本発明の第８の実施形態の好例として、珪素原子濃度を3×10^{18}原子／cm^3とするｎ形発光層につき、珪素原子濃度を3×10^{18}原子／cm^3に調節したｎ形のリン化硼素層からなる第２のリン化硼素系半導体層を接合させる例がある。第２のリン化硼素系半導体層の内部、特に、層厚方向での第ＩＶ族元素の原子濃度の分布を均一とする程、発光層から第２のリン化硼素系半導体層への第ＩＶ族元素の拡散を抑制するに効果を上げられる。また、発光層を挟持する伝導形を相違する第１及び第２のリン化硼素系半導体層を、同一の材料で、しかも同一の層厚の半導体層から構成することにより、発光層の上下方向から発光層へ印加される歪の量を均等とすれば、発光層から第１及び第２のリン化硼素系半導体層への第ＩＶ族元素の拡散を抑制するにより効果が奏される。

【００２９】本発明の第９の実施形態では、第２のリン化硼素系半導体層並びに発光層に存在させる第ＩＶ族元素を珪素（Ｓｉ）とする。珪素は第ＩＶ族元素の中でも難拡散性の元素であり、例えば、第２のリン化硼素系半導体層から発光層への拡散を抑制するに好都合となる。更に、発光層の珪素の原子濃度を基準として±３０％以内に差異を小とする珪素原子濃度の第２のリン化硼素系半導体層は、発光層への珪素原子の拡散を抑止し、発光層内の珪素原子濃度を最適に維持するに更に有効となる。例えば、一構成例として、珪素原子濃度を約4×10^{18}原子／cm^3とするｎ形$Ga_XIn_{1-X}N$（$0\leqq X\leqq1$）発光層と、珪素原子濃度を約5×10^{18}原子／cm^3とする第１及び第２のリン化硼素（ＢＰ）層とのヘテロ接合構造がある。

【００３０】仮に、第１の伝導形をｐ形とした場合、第１のリン化硼素系半導体層は例えば、アンドープでｐ形のリン化硼素（ＢＰ）層から構成できる。アンドープのｐ形リン化硼素（ＢＰ）には、アクセプタ成分として働く、リン空孔を占有する硼素原子が多量に存在している。従って、第１のリン化硼素系半導体層をなすアンドープのｐ形リン化硼素（ＢＰ）層に、上記の如く10^{18} cm^{-3}～10^{19} cm^{-3}未満の原子濃度で珪素原子を含有させたところで、アンドープｐ形リン化硼素（ＢＰ）層の正孔（ｈｏｌｅ）濃度をさして減少させるに至らず、従って、伝導形は変化しない。一方、第１の伝導形をｎ形とし、第１のリン化硼素系半導体層を例えば、アンドープのｎ形リン化硼素（ＢＰ）から構成する場合にあっても、アンドープのｎ形ＢＰ層には、例えば10^{18} cm^{-3}～10^{19} cm^{-3}未満の濃度の珪素原子を約２桁程度上

回る高濃度で、ドナー成分の硼素空孔を占有するリン原子が存在している。従って、縦しんば、両性不純物である珪素がアクセプタとして作用したところで、空孔が関与した多量のドナーを充分に電気的に補償（ｃｏｍｐｅｎｓａｔｅ）できず、第1のリン化硼素系半導体層の伝導形はｎ形に維持される。故に、本発明の第１０の実施形態では、第ＩＶ族元素の原子濃度を上記の空孔の関与するドナー或いはアクセプタ成分の濃度以下として第1及び第2のリン化硼素系半導体層を構成する。これらの空孔の関与するドナーまたはアクセプタを電気的に補償するために第ＩＶ族元素を多量にドーピングしたところで、固溶度を越えた多量のドーピングを施すこととなり、ドーパントを含む析出物の出現等に起因して、粗雑で平坦性に欠けるリン化硼素系半導体層がもたらされるのみである。発光層に対する例えば、障壁（ｃｌａｄ）層を構成するための低抵抗のリン化硼素系半導体層は、本発明の記す如く、アンドープのリン化硼素系半導体層によって、最も好適に且つ簡便に構成できるものである。

【００３１】

【作用】伝導形を相違する第1及び第2のリン化硼素系半導体層に含有される第ＩＶ族元素は、発光層に故意に添加（ドーピング）された第ＩＶ族元素の第1及び第2のリン化硼素系半導体層への拡散を抑制する作用を有し、発光層の内部の第ＩＶ族元素の原子濃度を、高強度の発光をもたらすに最適な濃度に維持する作用を有する。

【００３２】第1及び第2のリン化硼素系半導体層に含有される第ＩＶ族元素としての珪素は、アンドープ状態に於ける第1及び第2のリン化硼素系半導体層の伝導形を変化させることなく、両層より発光層への原子拡散、或いはその逆方向の拡散を抑制するに有効な第ＩＶ族元素種として作用する。

【００３３】

【実施例】（第1実施例）本文中に記載の第1の伝導形をｎ形とし、第2の伝導形をｐ形として、ｎ形の第1のリン化硼素系半導体層とｐ形の第2のリン化硼素系半導体層とを利用してリン化硼素系半導体ＬＥＤを構成する場合を例にして、本発明を具体的に説明する。

【００３４】第1実施例に係わるＬＥＤ１Ｂの平面模式図を図1に示す。また、図1に示す破線Ｘ－Ｘ’に沿ったＬＥＤ１Ｂの断面模式図を図2に示す。

【００３５】ＬＥＤ１Ｂ用途の積層構造体１Ａは、（１１１）結晶面を表面とするアンチモン（Ｓｂ）ドープのｎ形Ｓｉ単結晶を基板１０１として形成した。基板１０１上には、トリエチル硼素（$(C_2H_5)_3B$）／ホスフィン（PH_3）／水素（H_2）系常圧ＭＯＣＶＤ法により、３５０℃で、ａｓ－ｇｒｏｗｎ状態で非晶質を主体とするリン化硼素からなる緩衝層１０２を堆積した。緩衝層１０２の層厚は５ｎｍとした。

【００３６】緩衝層１０２の成膜を終了した後、基板１０１の温度を１０５０℃に上昇させた。昇温後、上記のＭＯＣＶＤ気相成長手段を利用して、緩衝層１０２の表面上に、アンドープのｎ形リン化硼素（ＢＰ）層からなる層厚を約３３０ｎｍとする第1のリン化硼素系半導体層１０３を積層した。第1の伝導形（本第1実施例では、ｎ形）の第1のリン化硼素系半導体層１０３の成膜を終了した後に、１０５０℃に於いて、ホスフィン（PH_3）と水素（H_2）とを混合した雰囲気内で同層を１０分間に亘り保持して、珪素単結晶基板１０１から拡散して来る珪素原子の第1のリン化硼素系半導体層１０３の内部への取り込みを促した。一般的な2次イオン質量分析法（ＳＩＭＳ）に依り、第1のリン化硼素系半導体層１０３の内部の珪素原子濃度は約4×10^{18} cm^{-3}と定量された。第1のリン化硼素系半導体層１０３のキャリア濃度は約8×10^{18} cm^{-3}であった。また、第1のリン化硼素系半導体層１０３をなす単量体のＢＰ層の室温での禁止帯幅は、屈折率（η）と消衰係数（κ）との積値（$=2\cdot\eta\cdot\kappa$）の光子エネルギー依存性から、約３．０ｅＶと求められた。

【００３７】第1のリン化硼素系半導体層１０３上には、トリメチルガリウム（$(CH_3)_3Ga$）／トリメチルインジウム（$(CH_3)_3In$）／アンモニア（NH_3）／H_2系常圧ＭＯＣＶＤ法により、８５０℃に於いて、ｎ形の窒化ガリウム・インジウム（$Ga_{0.94}In_{0.06}N$）からなる発光層１０４を積層した。発光層１０４の成膜時には、ジシラン（Si_2H_6）－水素（H_2）混合ガスを使用して、珪素（Ｓｉ）をドーピングした。発光層１０４への珪素のドーピング量は、同層１０４内の珪素原子濃度が約5×10^{18} cm^{-3}となる様に設定した。発光層１０４の層厚は５０ｎｍとした。

【００３８】発光層１０４の表面上には、第2の伝導形であるｐ形のリン化硼素（ＢＰ）からなる第2のリン化硼素系半導体層１０５を積層した。第2の伝導形（本第1実施例では、ｐ形）の第2のリン化硼素系半導体層１０５は、第2のリン化硼素系半導体層の場合と同じ（$(C_2H_5)_3B$／PH_3／H_2系常圧ＭＯＣＶＤ法により、８５０℃で成膜した。第2のリン化硼素系半導体層１０５の成膜時には、同層１０５内に残留（ｒｅｓｉｄｕａｌ）している珪素の原子濃度が約2×10^{17} cm^{-3}であるのに鑑み、合計の珪素原子濃度が約4×10^{18} cm^{-3}となる様に、ジシラン－水素混合ガスを利用して珪素をドーピングした。第2のリン化硼素系半導体層１０５のキャリア濃度は約1×10^{19} cm^{-3}とした。層厚は、第1のリン化硼素系半導体層１０３と同じく約３３０ｎｍとした。第2のリン化硼素系半導体層１０５も、第1のリン化硼素系半導体層１０３と同様に、室温での禁止帯幅を約３．０ｅＶとする単量体のリン化硼素（ＢＰ）より構成した。

【００３９】伝導形を相違する第1及び第2のリン化硼

素系半導体層１０３、１０５と、発光層１０４とからｐｎ接合型ダブルヘテロ接合（ＤＨ）構造型の発光部を構成した。図３に一般的なＳＩＭＳ分析に依る発光部を構成する各構成層１０３～１０５の深さ方向の珪素原子濃度の定量結果を示す。発光層１０４の珪素原子濃度を基準として、第１及び第２のリン化硼素系半導体層１０３、１０５の珪素原子濃度は約０．８倍となった。即ち、発光層１０４の珪素原子濃度に比較して、約２０％、低濃度となった。また、図３に示す如く、各構成層１０３～１０５の深さ方向（膜厚方向）で珪素原子は略一様に分布しているのが認められた。内部発光層１０４と第１及び第２のリン化硼素系半導体層１０３、１０５とで珪素原子濃度に均衡が保たれていたこと、並びに、発光層１０４を挟持する第１及び第２のリン化硼素系半導体層１０３、１０５を同一物質で、しかも同一の層厚の半導体材料（＝ＢＰ）から構成したために、発光層１０４から第１または第２のリン化硼素系半導体層１０３、１０５への珪素原子の拡散、またはその逆方向への拡散は抑制されたと判断された。

【００４０】ｐ形の第２のリン化硼素系半導体層１０５の表面の中央部には、同層１０５に接触する側に金・亜鉛（Ａｕ・Ｚｎ）合金からなるオーミック（Ｏｈｍｉｃ）電極を配置したＡｕ・Ｚｎ／ニッケル（Ｎｉ）／金（Ａｕ）の３層重層構造からなる表面電極１０６を設けた。結線用の台座（ｐａｄ）電極を兼ねる表面電極１０６は、直径を約１２０μｍとする円形の電極とした。また、ｎ形Ｓｉ単結晶基板１０１の裏面の略全面には、裏面電極１０７としてアルミニウム・アンチモン（Ａｌ・Ｓｂ）合金からなるオーミック電極を配置してＬＥＤ１Ｂを構成した。Ａｌ・Ｓｂ蒸着膜の膜厚は約２μｍとした。表面及び裏面電極１０６、１０７を形成した後、基板１０１をなすＳｉ単結晶を［２１１］方向に平行及び垂直な方向に裁断して、一辺を約３５０μｍとする正方形のＬＥＤ１Ｂとした。

【００４１】表面電極１０６と裏面電極１０７との間に順方向に２０ミリアンペア（ｍＡ）の動作電流を通流した際には、ＬＥＤ１Ｂから波長を約４３０ｎｍとする青紫帯光が発せられた。一般的な積分球を利用して測定されるチップ（ｃｈｉｐ）状態での輝度は９ミリカンデラ（ｍｃｄ）となり、高発光強度のＬＥＤ１Ｂが提供された。また、順方向電圧（Ｖｆ、但し順方向電流＝２０ｍＡ）は約３Ｖであり、逆方向電圧（V_R、但し逆方向電流＝１０μＡ）は５Ｖ以上となった。この良好な整流特性から、発光層１０４と第１及び第２のリン化硼素系半導体層１０３、１０５との間での珪素原子の拡散に因るヘテロ接合界面の乱雑化は（光技術共同研究所編著、「光電子集積回路の基礎技術」（１９８９年８月２０日、（株）オーム社発行、第１版第１刷）、３７１～３８４頁参照）抑止されているのが教示された。

【００４２】（第２実施例）第１の伝導形をｐ形とし、第２の伝導形をｎ形として、ｐ形の第１のリン化硼素系半導体層とｎ形の第２のリン化硼素系半導体層とを利用してリン化硼素系半導体ＬＥＤを構成する場合を例にして、本発明を具体的に説明する。

【００４３】本第２実施例に係わるＬＥＤ２Ｂの断面模式図を図４に示す。図４に示す積層構造体２Ａに於いて、図１及び図２に例示した積層構造体１Ａと同一の構成要素については図１または図２と同一の符号を付してある。

【００４４】ＬＥＤ２Ｂ用途の積層構造体２Ａは、（１１１）結晶面を表面とする硼素（Ｂ）ドープのｐ形Ｓｉ単結晶を基板１０１として形成した。

【００４５】基板１０１の表面には、$(C_2H_5)_3B/PH_3/H_2$系減圧ＭＯＣＶＤ法に依り、１０７５℃でアンドープでｐ形リン化硼素（ＢＰ）層からなる第１のリン化硼素系半導体層１０３を積層した。成膜時の圧力は約０．２気圧に保持した。第１の伝導形（本第２実施例では、ｐ形）の第１のリン化硼素系半導体層１０３の成膜を果たす１５分間の間に、珪素単結晶基板１０１より侵入、拡散して来る珪素原子に因り、層１０３の内部の珪素原子濃度は約7×10^{18} cm^{-3}に達した。珪素原子濃度がこの様な高濃度となっても、熱起電力の向きからして（本文中に記載の「半導体技術（上）」、１１９～１２０頁参照）、同層１０３はｐ形の伝導性を維持しており、そのキャリア濃度は約2×10^{19} cm^{-3}であることが、別途、確認されている。また、第１のリン化硼素系半導体層１０３の層厚は約２１０ｎｍとした。第１のリン化硼素系半導体層１０３をなす単量体のＢＰ層の室温での禁止帯幅は約３．０ｅＶであった。

【００４６】また、第１のリン化硼素系半導体層１０３は、ＭＯＣＶＤ反応系へのPH_3と$(C_2H_5)_3B$との供給量比率（＝$PH_3/(C_2H_5)_3B$）を９０とし、また、成膜速度を３０ｎｍ／分として成膜したために、内部に双晶１０８を略均一な密度で含むものとなった。双晶１０８はリン化硼素（ＢＰ）の｛１１１｝－結晶面を双晶境界面とするものであった。双晶は一種の積層欠陥（ｓｔａｃｋｉｎｇ　ｆａｕｌｔ）とも見なせるが（坂公恭著、「結晶電子顕微鏡学」（１９９７年１１月２５日、（株）内田老鶴圃発行第１版）、１１１～１１２頁参照）、イントリンシック（ｉｎｔｒｉｎｓｉｃ）型かエクストリンシック（ｅｘｔｒｉｎｓｉｃ）型の何れかの様式の積層欠陥（上記の「結晶電子顕微鏡学」、１４１頁参照）かは明確に判別するに至らなかった。

【００４７】第１のリン化硼素系半導体層１０３上には、$(CH_3)_3Ga/(CH_3)_3In/NH_3/H_2$系減圧ＭＯＣＶＤ法により、８００℃でに於いて、Ｓｉをドーピングしたｎ形窒化ガリウム・インジウム（$Ga_{0.90}In_{0.10}N$）からなる発光層１０４を積層した。発光層１０４は、約０．８気圧の減圧下で成膜した。層厚は約５０ｎｍとした。発光層１０４の成膜時には、Si_2H_6

$-H_2$混合ガスを使用して、層内の珪素原子濃度が約７×１０^{18} ｃｍ$^{-3}$ となる様に珪素をドーピングした。第１のリン化硼素系半導体層１０３の内部の上記の珪素元素濃度は、リン（Ｐ）空孔を占有する硼素（Ｂ）原子の濃度より桁違いに低く、同層１０３の表面は平坦性に優れるものでなった。このため、第１のリン化硼素系半導体層１０３上に形成した発光層１０４の表面は突起も無く平坦となった。

【００４８】発光層１０４の表面上には、ｎ形のリン化硼素（ＢＰ）からなる第２のリン化硼素系半導体層１０５を積層した。第２の伝導形（本第２実施例では、ｎ形）の第２のリン化硼素系半導体層１０５の成膜時には、同層１０５内の珪素原子の残留濃度が約４×１０^{17} ｃｍ$^{-3}$ であるのに鑑み、合計の珪素原子濃度が約７×１０^{18} ｃｍ$^{-3}$ となる様に、ジシラン－水素混合ガスを利用して珪素をドーピングした。この珪素原子濃度は、硼素（Ｂ）の空孔を占めるリン（Ｐ）原子の濃度より遥かに低く、従って、第２のリン化硼素系半導体層の伝導形の反転は認められなかった。また、この様な珪素原子濃度では、珪素を含む析出物の発生は認められず、第２のリン化硼素系半導体層１０５の平坦な表面を有する連続膜となった。第２のリン化硼素系半導体層１０５のキャリア濃度は約１×１０^{19} ｃｍ$^{-3}$ とした。層厚は、第１のリン化硼素系半導体層１０３と同じく約２１０ｎｍとした。第２のリン化硼素系半導体層１０５は、室温での禁止帯幅を約３．０ｅＶとする単量体のリン化硼素（ＢＰ）より構成した。伝導形を相違する第１及び第２のリン化硼素系半導体層１０３、１０５と、発光層１０４とからｐｎ接合型ダブルヘテロ接合（ＤＨ）構造型の発光部を構成した。

【００４９】ｎ形の第２のリン化硼素系半導体層１０５の表面の中央部には、表面電極１０６を配置した。表面電極１０６は、第２のリン化硼素系半導体層１０５に接触する側を金・ゲルマニウム（Ａｕ・Ｇｅ）合金膜とする、Ａｕ・Ｇｅ／Ｎｉ／Ａｕ３層重層膜から構成した。台座電極を兼ねる円形の表面電極１０６の直径は、約１１０μｍとした。ｐ形Ｓｉ単結晶基板１０１の裏面の略全面には、裏面電極１０７としてアルミニウム（Ａｌ）からなるオーミック電極を配置してＬＥＤ２Ｂを構成した。Ａｌ真空蒸着膜の膜厚は約３μｍとした。表面及び裏面電極１０６、１０７を形成した後、Ｓｉ単結晶１０１を［２１１］方向に平行及び垂直な方向に裁断して、一辺を約３５０μｍとする正方形のＬＥＤ２Ｂとした。

【００５０】表面電極１０６と裏面電極１０７との間に順方向に２０ミリアンペア（ｍＡ）の動作電流を通流した際の発光中心波長は約４４０ｎｍとなった。発光層１０４と、障壁層の第１及び第２のリン化硼素系半導体層１０３、１０５との珪素原子濃度を同一として、拡散に因る発光層１０４内の珪素原子濃度の変動を抑止したため、一般的な積分球を利用して測定されるチップ（ｃｈｉｐ）状態での輝度は約１０ミリカンデラ（ｍｃｄ）となり、高発光強度のＬＥＤ２Ｂが提供された。また、良好な整流特性が発揮され、電流－電圧（Ｉ－Ｖ）特性から求めた順方向電圧（＝Ｖｆ）は約３Ｖ（但し、順方向電流＝２０ｍＡ）で、逆方向電圧は７Ｖ（但し、逆方向電流＝１０μＡ）であり、高耐圧でもあるＬＥＤ２Ｂが提供された。

【００５１】

【発明の効果】本発明に依れば、珪素単結晶からなる基板上に設けられ、高強度の発光をもたらすに最適な原子濃度で添加された第ＩＶ族元素を含むＩＩＩ－Ｖ族半導体からなる発光層に、第ＩＶ族元素を含み伝導形を相違する第１および第２のリン化硼素系半導体層を接合させてｐｎ接合型ヘテロ接合構造を構成することとしたので、例えば、発光層からの第ＩＶ族元素の外部拡散を抑制するに効果を奏し、発光層内の第ＩＶ族元素の原子濃度を発光強度の観点から最適な濃度に維持することができ、高発光強度の発光素子を提供できる。

【００５２】特に、本発明では、発光層を挟持してヘテロ接合構造をなす第１または第２のリン化硼素系半導体層を、発光層と略同等の第ＩＶ族元素の原子濃度を有する第１または第２の伝導形の導電性半導体層から構成することとしたので、原子濃度の差異に起因する第ＩＶ族元素の相互拡散を抑制するに効果を上げられ、発光層内の第ＩＶ族元素の原子濃度を発光強度の観点から最適な濃度に維持することができ、高発光強度の発光素子をもたらすに貢献できる。

【００５３】また特に、本発明では、発光を挟持してヘテロ接合構造をなす第１または第２のリン化硼素系半導体層を、発光層にドーピングしたものと同一の第ＩＶ族元素を含む第１または第２の伝導形の導電性半導体層から構成することとしたので、原子濃度の差異に起因する第ＩＶ族元素の相互拡散を抑制するに更に、効果を上げられ、発光層内の第ＩＶ族元素の原子濃度を発光強度の観点から最適な濃度に維持することができ、高発光強度の発光素子をもたらすことができる。

【００５４】また特に、本発明では、発光を挟持してヘテロ接合構造をなす第１または第２のリン化硼素系半導体層を、発光層にドーピングしたものと同一の第ＩＶ族元素を、略同一の原子濃度で含む第１または第２の伝導形の導電性半導体層から構成することとしたので、原子濃度の差異に起因する第ＩＶ族元素の相互拡散を抑止するに更に、効果を上げられ、発光層内の第ＩＶ族元素の原子濃度を発光強度の観点から最適な濃度に維持することができ、高発光強度の発光素子をもたらすことができる。

【００５５】更に、本発明では、第ＩＶ族元素の原子濃度を、硼素（Ｂ）空孔を占有するリン（Ｐ）原子またはリン空孔を占める硼素（Ｂ）原子の濃度以下とした第１または第２の伝導形のリン化硼素系半導体層を発光層に

接合させる積層構成としたので、アンドープ状態での伝導形を維持しつつ、表面の平坦性に優れ得る発光層をもたらすに効果を奏し、しいては伝導形に依って異なる不純物をドーピングする煩雑性を回避して高強度の発光をもたらす発光素子を簡便に提供できる。

【図面の簡単な説明】

【図１】本発明の第１実施例に係るＬＥＤの平面模式図である。

【図２】図１に示すＬＥＤの破線Ｘ－Ｘ'に沿った断面模式図である。

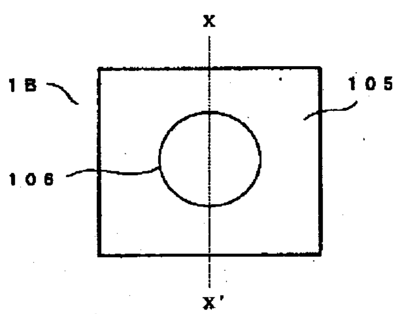
【図３】本発明の第１実施例に係るＬＥＤ中の珪素原子の深さ方向の濃度分布を示す図である。

【図４】本発明の第２実施例に係るＬＥＤの断面模式図＊＊である。

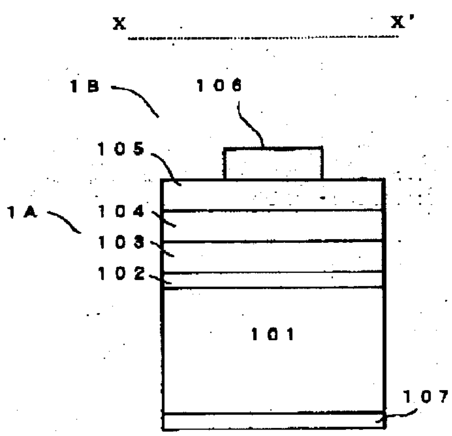
【符号の説明】

１Ａ、２Ａ　積層構造体
１Ｂ、２Ｂ　ＬＥＤ
１０１　基板
１０２　緩衝層
１０３　第１のリン化硼素系半導体層
１０４　発光層
１０５　第２のリン化硼素系半導体層
１０６　表面電極
１０７　裏面電極
１０８　双晶

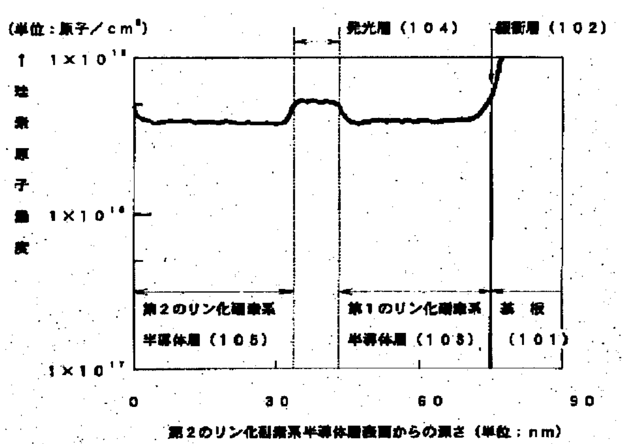
【図１】



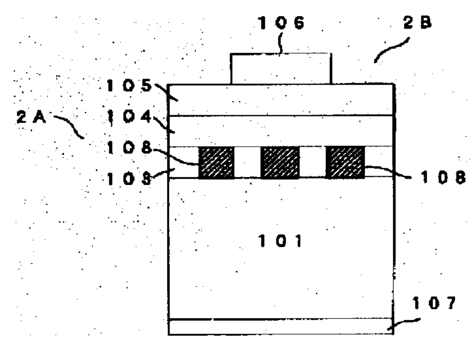
【図２】



【図３】



【図４】



PATENT ABSTRACTS OF JAPAN

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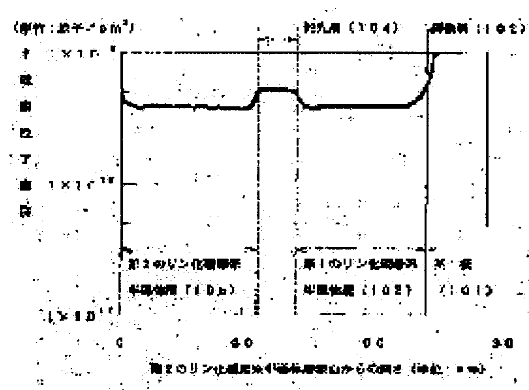
(72)Inventor : UDAGAWA TAKASHI

(54) pn JUNCTION TYPE BORON PHOSPHIDE GROUP SEMICONDUCTOR LIGHT EMITTING ELEMENT AND ITS MANUFACTURING METHOD

(57)Abstract:
PROBLEM TO BE SOLVED: To suppress an external diffusion of a IV-element from a light emitting layer in a boron phosphide group semiconductor light emitting element, and to maintain an atom concentration of the IV-element in the light emitting layer at optimum concentration from the viewpoint of light emission intensity.

SOLUTION: The boron phosphide group semiconductor light emitting element is provided with the light emitting layer consisting of a first boron phosphide group semiconductor layer, and a III-V semiconductor layer obtained by intentionally adding the IV-element and pn junction type hetero junction structure consisting of a second boron phosphide group semiconductor layer. The first boron phosphide group semiconductor layer is constituted of an undoped first conductive boron phosphide group semiconductor containing the IV-element, and the second boron phosphide group semiconductor layer is constituted of a second conductive boron phosphide group semiconductor layer containing the IV-element.



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CLAIMS

[Claim(s)]

[Claim 1] The substrate which consists of a silicon (Si) single crystal of the 1st conduction type, and the 1st Lynn-ized boron system semi-conductor layer of the 1st conduction type formed on this substrate, the [which was prepared on the 1st Lynn-ized boron system semi-conductor layer / which has the 1st cr 2nd conduction type / on a periodic table of the elements] -- with the luminous layer which consists of an III-V group semi-conductor layer which added IV group element intentionally It has the 2nd Lynn-ized boron system semi-conductor layer of the 2nd conduction type formed on the luminous layer. In the pn junction mold Lynn-ized boron system semi-conductor light emitting device equipped with the pn junction mold hetero (different species) junction structure which consists of the 1st Lynn-ized boron system semi-conductor layer, a luminous layer, and the 2nd Lynn-ized boron system semi-conductor layer It constitutes from a Lynn-ized boron system semi-conductor of the 1st conduction type of undoping containing IV group element. the 1st Lynn-ized boron system semi-conductor layer -- the -- the 2nd Lynn-ized boron system semi-conductor layer -- the -- the pn junction mold Lynn-ized boron system semi-conductor light emitting device characterized by constituting from a Lynn-ized boron system semi-conductor layer containing IV group element of the 2nd conduction type opposite to the 1st conduction type.

[Claim 2] the [of the same kind as what is contained in the 1st Lynn-ized boron system semi-conductor layer at a luminous layer] -- the pn junction mold Lynn-ized boron system semi-conductor light emitting device according to claim 1 characterized by containing IV group element.

[Claim 3] the [which is contained in the 1st Lynn-ized boron system semi-conductor layer] -- the atomic concentration of IV group element -- the [inside a luminous layer] -- the pn junction mold Lynn-ized boron system semi-conductor light emitting device according to claim 1 or 2 characterized by considering as less than **30% to the atomic concentration of IV group element.

[Claim 4] the [which is contained in the 1st Lynn-ized boron system semi-conductor layer and luminous layer] -- a pn junction mold Lynn-ized boron system semi-conductor light emitting device given in claim 1 characterized by using IV group element as silicon (Si) thru/or any 1 term of 3.

[Claim 5] A pn junction mold Lynn-ized boron system semi-conductor light emitting device given in claim 1 characterized by constituting the 2nd Lynn-ized boron system semi-conductor layer from a Lynn-ized boron system semi-conductor layer of the 2nd conduction type of undoping thru/or any 1 term of 4.

[Claim 6] the 2nd Lynn-ized boron system semi-conductor layer -- the -- a pn junction mold Lynn-ized boron system semi-conductor light emitting device given in claim 1 characterized by constituting IV group element from a Lynn-ized boron system semi-conductor layer of the 2nd conduction type added intentionally thru/or any 1 term of 4.

[Claim 7] having added in the 2nd Lynn-ized boron system semi-conductor layer at the luminous layer -- the [of the same kind] -- a pn junction mold Lynn-ized boron system semi-conductor light emitting device given in claim 1 characterized by containing IV group element thru/or any 1 term of 6.

[Claim 8] the [which is contained in the 2nd Lynn-ized boron system semi-conductor layer] -- the atomic concentration of IV group element -- the [inside a luminous layer] -- a pn junction mold Lynn-ized boron system semi-conductor light emitting device given in claim 1 characterized by considering as less than **30% to the atomic concentration of IV group element thru/or any 1 term of 7.

[Claim 9] the [which is contained in the 2nd Lynn-ized boron system semi-conductor layer and luminous layer] -- a pn junction mold Lynn-ized boron system semi-conductor light emitting device given in claim 1 characterized by what IV group element was used as silicon (Si) for thru/or any 1 term of 8.

[Claim 10] The pn junction mold Lynn-ized boron system semi-conductor light emitting device according to claim 4 characterized by carrying out to which [of the concentration of the Lynn atom which occupies a boron hole for the atomic concentration of the silicon contained in the 1st Lynn-ized boron system semi-conductor layer, or the concentration of the boron atom which occupies the Lynn hole] below concentration.

[Claim 11] The pn junction mold Lynn-ized boron system semi-conductor light emitting device according to claim 9 characterized by carrying out to which [of the concentration of the Lynn atom which occupies a boron hole for the atomic concentration of the silicon contained in the 2nd Lynn-ized boron system semi-conductor layer, or the concentration of the boron atom which occupies the Lynn hole] below concentration.

[Claim 12] MOCVD -- the manufacture approach of the pn junction mold Lynn-ized boron system semi-conductor light emitting device according to claim 1 to 11 which is 1000-1200 degrees C in temperature about

the Lynn-ized boron system semi-conductor layer of p mold, and is characterized by forming the Lynn-ized boron system semi-conductor layer of n mold at the temperature of 750-950 degrees C by law.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the technique for constituting the Lynn-ized boron system semiconductor device equipped with heterojunction structure, and relates to the technique for obtaining the Lynn-ized boron system semi-conductor light emitting device which presents high luminescence reinforcement especially.
[0002]
[Description of the Prior Art] It is in the former and Lynn-ized boron (BP) is found as a group's III-V semiconducter kind (refer to Nature, 179, and No. 4569 (1957) or 1075 pages). Moreover, since Lynn-ized boron (BP) is the semi-conductor of a indirect transition mold (refer to the Teramoto ****, "semiconductor device introduction" (March 30, 1995, Baifukan Issue First edition), and 28 pages), it is supposed that it is not become a suitable ingredient to form the luminous layer of a semi-conductor light emitting device. For this reason, in the Lynn-ized boron system semi-conductor light emitting diode (LED) which comes to have the conventional Lynn-ized boron system semi-conductor layer, the Lynn-ized boron system semi-conductor layers, such as Lynn-ized boron, are used for constituting the buffer coat chiefly prepared on the substrate which consists of a silicon single crystal (silicon) (refer to U.S. Pat. No. 6 and No. 069 or 021). Moreover, in the laser diode (LD), it is used as a contact (contact) layer for preparing an ohmic (Ohmic) electrode, for example (refer to JP,2-288388,A).
[0003] On the other hand, it is in a semi-conductor light emitting device, and, usually a luminous layer consists of semiconductor materials of the direct transition mold which is excellent in radiative-recombination effectiveness as compared with a indirect transition mold. The luminous layer is mainly conventionally constituted from the gallium nitride indium (GaXIn1-XN:0 <=X<=1) by the Lynn-ized boron system semi-conductor LED (refer to JP,55-3834,B). the [which is especially carried by periodic tables of the elements, such as silicon (Si) and germanium (germanium),] -- it has been usually to constitute a luminous layer from GaXIn1-XN (0<=X<=1) which added IV group element intentionally (refer to JP,6-260680,A). the -- it is because the GaXIn1-XN (0<=X<=1) luminous layer which brings about luminescence of high reinforcement can be offered by doping (doping) of IV group element (refer to the Japan patent No. 2560963 official report). In order to be in a semi-conductor light emitting device and to obtain luminescence of high intensity, usually a light-emitting part is made into the double different-species (double hetero:DH) structure of the pn junction mold which consists of a luminous layer and an obstruction (clad) layer of p form which pinches a luminous layer, or n form (refer to JP,6-260283,A).
[0004] the former -- setting -- the Lynn-ized boron system semi-conductor layer of p form -- the [of element periodic law] -- it usually comes out to add and obtain magnesium (Mg), zinc (Zn), etc. belonging to II group intentionally (doping), and there is (refer to ** JP,2-275682,A, ** JP,2-288371,A, ** JP,2-288388,A, ** JP,10-242514,A, ** JP,10-242515,A, and ** JP,10-242567,A). moreover, the Lynn-ized boron system semi-conductor layer of n form -- the [, such as silicon (Si),] -- it may depend on doping of IV group element -- usually -- ** -- it has become (for example, refer to above-mentioned JP,2-288388,A). In view of such a conventional technical example, p form barrier layer which makes the light-emitting part of pn junction mold DH structure consists of p form Lynn-ized boron system semi-conductor layers which doped Mg or Zn. Moreover, n form barrier layer consists of n form Lynn-ized boron system semi-conductor layers which doped silicon (refer to application for patent No. 158282 [2001 to]).
[0005] the [on the other hand,] -- it is indicated that the silicon (Si) which is IV group element works as an amphoteric (amphoteric impurity) like the case where other groups III-V semiconducter are received, to the Lynn-ized boron system semi-conductor (refer to the Shono Katsufusa work, "semiconductor technology (above)" (June 25, 1992, University of Tokyo Press issue 9 **), and 77 pages). Moreover, about the Lynn-ized boron semi-conductor layer, the technique of being in the condition of the so-called undoping (undope) which does not add an impurity intentionally, and obtaining the semi-conductor layer of n form or p form by ****(ing) and choosing the vapor growth temperature of the Lynn-ized boron layer is also indicated (refer to the above-mentioned "semiconductor technology (above) and 76 - 77 pages). It is supposed that existence with a boron hole and the Lynn hole is participating in the decision of the conduction type of the Lynn-ized boron semi-conductor layer of undoping (the Shono Katsufusa work, "semiconductor technology 100 collection of the VLSI age [III]" (refer to April 1, Showa 57, Ohm-Sha Issue, "electronic magazine electronics", the 27th volume of the No. [4] appendix, and 86 - 87 pages).).

[0006]
[Problem(s) to be Solved by the Invention] Nevertheless, with the conventional technique, the impurity (dopant) of a class which is different specially in the Lynn-ized boron system semi-conductor layer which is different in conduction type had been doped and obtained. Therefore, the trouble of hitting acquiring the pn junction structure which consists of a Lynn-ized boron system semi-conductor layer suited conduction type at the complicatedness which must change a dopant kind specially and must obtain the Lynn-ized boron system semi-conductor layer of n form or p form. the [moreover, / which was doped to the luminous layer even if it tried when the light-emitting part of DH structure of a pn junction mold would be obtained as a barrier layer, using ******** and the Lynn-ized boron system semi-conductor layer of undoping in order to avoid this complicated doping actuation] -- it has fully come to control being spread to the Lynn-ized boron system semi-conductor barrier layer of undoping of IV group element. the [moreover, / which was doped in order to bring about luminescence of high intensity like the above] -- since extent diffused to the Lynn-ized boron semi-conductor layer of undoping of IV group element, for example, silicon, is changed, the reinforcement of luminescence by which outgoing radiation is carried out from a luminous layer becomes unstable, and if it spreads, there is no yes in obtaining **** Lynn-ized boron system half ********** for the stable luminescence reinforcement very much.

[0007] It is in the Lynn-ized boron system semi-conductor light emitting device of the pn junction mold DH structure which makes a luminous layer the semi-conductor layer which comes to dope IV group element as an impurity. the [for example,] -- Diffusion of IV group element can be controlled. the [to the Lynn-ized boron system semi-conductor layer of undoping which can be formed simple] -- the [therefore, / inside the luminous layer added by concentration suitable in order to bring about high luminescence reinforcement] -- if the configuration which can avoid reduction of the concentration of IV group element is offered, it will become effective in obtaining the Lynn-ized boron system semi-conductor light emitting device which is stabilized and presents high luminescence reinforcement. Especially in this invention, the configuration of the light-emitting part of the heterojunction structure which takes effect is shown for bringing about the Lynn-ized boron system semi-conductor light emitting device of high luminescence reinforcement.

[0008]
[Means for Solving the Problem] Namely, the substrate with which this invention consists of a silicon (Si) single crystal of the (1) 1st conduction type, The 1st Lynn-ized boron system semi-conductor layer of the 1st conduction type formed on this substrate, the [which was prepared on the 1st Lynn-ized boron system semi-conductor layer / which has the 1st or 2nd conduction type / on a periodic table of the elements] -- with the luminous layer which consists of an III-V group semi-conductor layer which added IV group element intentionally It has the 2nd Lynn-ized boron system semi-conductor layer of the 2nd conduction type formed on the luminous layer. In the Lynn-ized boron system semi-conductor light emitting device equipped with the pn junction mold hetero (different species) junction structure which consists of the 1st Lynn-ized boron system semi-conductor layer, a luminous layer, and the 2nd Lynn-ized boron system semi-conductor layer It constitutes from a Lynn-ized boron system semi-conductor of the 1st conduction type of undoping containing IV group element. the 1st Lynn-ized boron system semi-conductor layer -- the -- the 2nd Lynn-ized boron system semi-conductor layer -- the -- the pn junction mold Lynn-ized boron system semi-conductor light emitting device characterized by constituting from a Lynn-ized boron system semi-conductor layer containing IV group element of the 2nd conduction type opposite to the 1st conduction type.

(2) the [of the same kind as what is contained in the 1st Lynn-ized boron system semi-conductor layer at a luminous layer] -- a pn junction mold Lynn-ized boron system semi-conductor light emitting device given in the above (1) characterized by containing IV group element.

(3) the [which is contained in the 1st Lynn-ized boron system semi-conductor layer] -- the atomic concentration of IV group element -- the [inside a luminous layer] -- a pn junction mold Lynn-ized boron system semi-conductor light emitting device the above (1) characterized by considering as less than **30% to the atomic concentration of IV group element, or given in (2).

(4) the [which is contained in the 1st Lynn-ized boron system semi-conductor layer and luminous layer] -- a pn junction mold Lynn-ized boron system semi-conductor light emitting device the above (1) characterized by using IV group element as silicon (Si) thru/or given in any 1 term of (3).

(5) The above (1) characterized by constituting the 2nd Lynn-ized boron system semi-conductor layer from a Lynn-ized boron system semi-conductor layer of the 2nd conduction type of undoping thru/or a pn junction mold Lynn-ized boron system semi-conductor light emitting device given in any 1 term of (4).

(6) the 2nd Lynn-ized boron system semi-conductor layer -- the -- a pn junction mold Lynn-ized boron system semi-conductor light emitting device the above (1) characterized by constituting IV group element from a Lynn-ized boron system semi-conductor layer of the 2nd conduction type added intentionally thru/or given in any 1 term of (4).

(7) having added in the 2nd Lynn-ized boron system semi-conductor layer at the luminous layer -- the [of the same kind] -- a pn junction mold Lynn-ized boron system semi-conductor light emitting device the above (1) characterized by containing IV group element thru/or given in any 1 term of (6).

(8) the [which is contained in the 2nd Lynn-ized boron system semi-conductor layer] -- the atomic concentration of IV group element -- the [inside a luminous layer] -- a pn junction mold Lynn-ized boron system semi-conductor light emitting device the above (1) characterized by considering as less than **30% to

the atomic concentration of IV group element thru/or given in any 1 term of (7).
(9) the [which is contained in the 2nd Lynn-ized boron system semi-conductor layer and luminous layer] -- a pn junction mold Lynn-ized boron system semi-conductor light emitting device the above (1) characterized by what IV group element was used as silicon (Si) for thru/or given in any 1 term of (8).
(10) A pn junction mold Lynn-ized boron system semi-conductor light emitting device given in the above (4) characterized by carrying out to which [of the concentration of the Lynn atom which occupies a boron hole for the atomic concentration of the silicon contained in the 1st Lynn-ized boron system semi-conductor layer, or the concentration of the boron atom which occupies the Lynn hole] below concentration.
(11) A pn junction mold Lynn-ized boron system semi-conductor light emitting device given in the above (9) characterized by what was done to which [of the concentration of the Lynn atom which occupies a boron hole for the atomic concentration of the silicon contained in the 2nd Lynn-ized boron system semi-conductor layer, or the concentration of the boron atom which occupies the Lynn hole] below concentration. It comes out. Moreover, this invention is the manufacture approach of a pn junction mold Lynn-ized boron system semi-conductor light emitting device the above (1) which is 1000-1200 degrees C in temperature about the Lynn-ized boron system semi-conductor layer of p mold, and is characterized by forming the Lynn-ized boron system semi-conductor layer of n mold at the temperature of 750-950 degrees C by the (12) MOCVD method thru/or given in (11). It comes out.
[0009]
[Embodiment of the Invention] In the 1st operation gestalt of this invention, {100}, {110} or {100}- that uses the {111} crystal faces as a front face, {110}-, and a {111}-silicon (Si) single crystal can be used for a substrate. Moreover, the silicon single crystal which makes it an include angle and uses abundance and the sloping crystal face as a front face, more for example than the {111} crystal faces can also be used as a substrate. Especially, as compared with the {100} crystal faces etc., the silicon atom exists in the {111} crystal faces of the silicon single crystal of a diamond (diamond) crystal structure mold by the higher consistency. For this reason, a {111}-Si single crystal serves as a substrate effective in preventing that the boron (B) atom and the Lynn (P) atom which constitute the upper Lynn-ized boron system semi-conductor layer are invaded or spread inside Si single crystal substrate. Any of n form or p form are sufficient as the conduction type of a silicon single crystal. By this invention, the 1st conduction type is tentatively called to the conduction type of the silicon single crystal which forms a substrate. Positive/negative and which polar ohmic (Ohmic) nature electrode can be laid for a conductive silicon single crystal as a rear-face electrode at the rear face of a substrate, then a substrate, and it can contribute for constituting a light emitting device simple. The low conductive single crystal substrate of specific resistance (resistivity) which makes resistivity especially more desirably less than [0.1mohm] contributes for bringing about LED with low forward voltage (the so-called Vf) below 1 milli ohm (mohms). Moreover, since it excels in heat dissipation nature, it becomes effective in constituting LD which brings about the stable oscillation.
[0010] The 1st Lynn-ized boron system compound semiconductor layer which carries out a laminating on a silicon single crystal substrate front face constitutes boron (B) and Lynn (P) for example, from BalphaaluminumbetaGagammaIn1-alpha-beta-gamma P1-deltaAsdelta (0< alpha<=1, 0<=beta<1, 0<=gamma<1, 0< alpha+beta+gamma <=1, 0<=delta<1) included as a configuration element. Moreover, for example, it can constitute from BalphaaluminumbetaGagammaIn1-alpha-beta-gamma P1-deltaNdelta (0< alpha<=1, 0<=beta<1, 0<=gamma<1, 0< alpha+beta+gamma <=1, 0<=delta<1). The 1st Lynn-ized boron system semi-conductor layer is a semi-conductor layer which approaches by the front face of a silicon single crystal substrate in [layer / below-mentioned / 2nd / Lynn-ized boron system semi-conductor] location, and is prepared. Moreover, let conduction type of the 1st Lynn-ized boron system semi-conductor layer be the 1st conduction type which is in agreement with the conduction type of the silicon single crystal which forms a substrate. For example, the case where p form Lynn-ized boron system semi-conductor layer of high resistance is prepared on the {111}-Si single crystal substrate of p form can be illustrated.
[0011] the 1st Lynn-ized boron system compound semiconductor layer -- especially -- a presentation (=alpha) and Lynn of boron (B) -- the boron and Lynn which carry out each presentation (= 1-delta) of (P) to more than 0.5 (= 50%) are included as a subject -- for example BalphaaluminumbetaGagammaIn1-alpha-beta-gamma P1-deltaAsdelta (0.5<=alpha<=1, 0<=beta<0.5, 0<=gamma<0.5, 0.5< alpha+beta+gamma <=1, 0<=delta<0.5), Or it can constitute from BalphaaluminumbetaGagammaIn1-alpha-beta-gamma P1-deltaNdelta (0.5<=alpha<=1, 0<=beta<0.5, 0<=gamma<0.5, 0.5< alpha+beta+gamma <=1, 0<=delta<0.5) suitably. From the Lynn-ized boron system semi-conductor mixed crystal which includes actively the boron which makes the presentation of boron (B) and Lynn (P) 0.5 or more respectively, and Lynn, there is an advantage to which the impurity which controls conduction type is not added intentionally (= doping), but the Lynn-ized boron system semi-conductor layer of the conductivity [**] of the 1st or 2nd conduction type is brought. That is, since the Lynn-ized boron system semi-conductor layer of the 1st conduction type can be formed by undoping, the complicated nature which changes the impurity kind therefore added to conduction type is avoidable for forming the Lynn-ized boron system semi-conductor layer of the 1st conduction type.
[0012] the 1st Lynn-ized boron system semi-conductor layer which has the 1st same conduction type as the silicon single crystal of a substrate -- the -- the [which doped in a luminous layer in order to make the reinforcement of luminescence emitted increase while released from the complicated actuation which dopes an impurity, when having constituted from an undoping layer containing IV group element] -- effect is taken by

controlling invasion into the 1st [of IV group element] Lynn-ized boron system semi-conductor layer, and diffusion. the [which is contained in the 1st Lynn-ized boron system semi-conductor layer] -- it is not necessary to necessarily limit IV group element to one kind the [the 1st Lynn-ized boron system semi-conductor layer of the 1st conduction type is made to contain] -- in IV group element, carbon (C), silicon (Si), germanium (germanium), tin (Sn), etc. can be illustrated. the [these] -- since it is in IV group element and carbon (C) and silicon (Si) are not notably diffused within groups III-V semiconducter, such as the Lynn-ized boron system semi-conductor layer, it is especially suitable. the [moreover, / which is especially included in the 1st Lynn-ized boron system semi-conductor layer] -- the [which doped IV group element to the luminous layer] -- the [the same as that of IV group element, then / of a luminous layer] -- effectiveness can be raised for controlling invasion in the 1st Lynn-ized boron system semi-conductor layer of IV group element, and diffusion. As an example of the 2nd operation gestalt of this invention, the 1st Lynn-ized boron system semi-conductor layer in which silicon was included may be prepared about a silicon dope luminous layer. Moreover, the example which prepares a carbon dope luminous layer on the 1st Lynn-ized boron system semi-conductor layer containing carbon can be given.

[0013] the 1st Lynn-ized boron system semi-conductor layer of the 1st conduction type containing carbon (C) and silicon (Si) -- the [these] -- there is an advantage which does not add IV group element intentionally but can also form **. For example, the 1st Lynn-ized boron system semi-conductor layer containing silicon is obtained simple by using a silicon single crystal as a substrate. If a silicon single crystal substrate is especially held in temperature of 1200 degrees C or less above 850 degrees C, the temperature of 750 degrees C - 1200 degrees C and the silicon isolated from the silicon single crystal will mix in the interior of the 1st Lynn-ized boron system semi-conductor layer conveniently, and can form the 1st Lynn-ized boron system semi-conductor layer containing silicon. Moreover, in forming the 1st Lynn-ized boron system semi-conductor layer, the 1st Lynn-ized boron system semi-conductor layer which contains the source of boron (B), then carbon for the functional group (function group) containing carbon (C) and the organic boron compound which added the saturation or the partial saturation aliphatic series functional group of the shape of the shape of a side chain and a straight chain especially can be formed simply. Namely, for example, methane (CH4), trimethyl arsenic (CH3) (3As), Even if it does not use anew carbon content compounds, such as a carbon tetrachloride (CCl4) and carbon tetrabromide (CBr4), as a carbonaceous dopant For example, if the carbon which is based on the pyrolysis of alkyl (alkyl) boron compounds, such as trimethyl boron (CH3) (3B) and boron triethyl (C2H5) (3B), and is generated is used, the 1st Lynn-ized boron system semi-conductor layer containing carbon is made simple, and can be formed. If it puts in another way, it can form simple with vapor growth means, such as the organic metal chemical depositing method (MOCVD law) which makes these alkyl boron compounds the source of boron.

[0014] the [, such as silicon (Si) included in the 1st Lynn-ized boron system semi-conductor layer of the 1st conduction type, or carbon (C),] -- the [by which the atomic concentration of IV group element is contained in a luminous layer] -- about 0.5 or more times of the atomic concentration of IV group element -- about -- it is desirable to consider as 2 double less or equal. the [in the 1st Lynn-ized boron system semi-conductor layer] -- if the atomic concentration of IV group element turns into high concentration exceeding the twice [about] of that of a luminous layer -- the [from the 1st Lynn-ized boron system semi-conductor layer to a luminous layer] -- diffusion of IV group element -- being generated -- the [in a luminous layer] -- it causes un-arranging [from which the atomic concentration of IV group element turns into high concentration at **]. the [on the contrary, / in a luminous layer] -- less than about 0.5 times [of the atomic concentration of IV group element] low concentration -- the -- the [which is turned to the interior of the 1st Lynn-ized boron system semi-conductor layer from a luminous layer in the 1st Lynn-ized boron system semi-conductor layer containing IV group element] -- since [this] diffusion of IV group element occurs notably -- the [inside a luminous layer] -- the atomic concentration of IV group element decreases and it produces un-arranging to bring about luminescence of high intensity. the [in the 1st Lynn-ized boron system semi-conductor layer] -- still more suitable one as atomic concentration of the sum total of IV group element -- the [in a luminous layer] -- the [of inside when the atomic concentration of IV group element and abbreviation are equal (i.e., a luminous layer)] -- it is the atomic concentration which is in **30% of within the limits to the atomic concentration of IV group element. the [of a luminous layer and the Lynn-ized boron system semi-conductor layer] -- the [which originates in the difference of the atomic concentration and is generated, so that the difference in the atomic concentration of IV group element is smallness] -- the counter diffusion of IV group element may be controlled more. the most suitable one -- the [of the 1st Lynn-ized boron system semi-conductor layer] -- the atomic concentration of IV group element is the case where they are it of a luminous layer, and this concentration. the [inside the 1st Lynn-ized boron system semi-conductor layer] -- the atomic concentration of IV group element can carry out a quantum like the case of a luminous layer using analysis means, such as secondary ion mass analysis (SIMS) and the Auger (Auger) electron spectroscopy analysis method.

[0015] as a way stage of the 3rd operation gestalt of this invention -- the [for example,] -- it is in the 1st Lynn-ized boron system semi-conductor layer which contains silicon (Si) as an IV group element, membrane formation temperature is adjusted, and the example which makes silicon atom concentration in a layer less than **30% on the basis of it of a luminous layer can be raised. Silicon atom concentration in a layer can be made into high concentration, so that membrane formation temperature, i.e., the retention temperature of a

silicon single crystal substrate, is made into an elevated temperature, and, so that the hot holding time is lengthened. For example, on the p form {111}-Si single crystal substrate held at 1050 degrees C of membrane formation temperature, p form Lynn-ized boron (BP) layer of undoping which sets silicon atom concentration to abbreviation 4x1017 atom / cm3 can be formed. If membrane formation temperature is made into the elevated temperature exceeding 1200 degrees C, the Lynn-ized boron crystal of the polymer of B6P of the rhombohedron crystal structure or B13P2 grade will become is easy to be formed. If the Lynn-ized boron polymer occurs in the 1st [of a cubic sphalerite crystal mold] Lynn-ized boron system semi-conductor layer, invasion into the layer of the silicon from a silicon single crystal substrate will arise notably through distortion or the crystal defect based and generated in the layer in the difference of a crystal mold. For this reason, sometimes the atomic concentration of the silicon in the 1st Lynn-ized boron system semi-conductor layer exceeds 5x1019 atom / cm3, and turns into high concentration at **, and the crystallinity of the 1st Lynn-ized boron system semi-conductor layer causes un-arranging [which becomes disorderly].
[0016] Moreover, when the buffer coat of an amorphous substance or polycrystal is prepared in the middle with the 1st Lynn-ized boron system semi-conductor layer on a silicon single crystal substrate, the buffer coat which consists of such a crystalline form has the operation which captures the silicon atom diffused from a substrate while easing the lattice mismatch of a silicon single crystal substrate and the 1st Lynn-ized boron system semi-conductor layer. Therefore, the concentration of the diffused silicon atom in the 1st Lynn-ized boron system semi-conductor layer may be low controlled compared with the case where the 1st Lynn-ized boron system semi-conductor layer is directly joined to a silicon single crystal substrate front face. The silicon atom captured by the buffer coat becomes abundant, so that the thickness of a buffer coat is thick. That is, the silicon atom concentration of the 1st Lynn-ized boron system semi-conductor layer is controllable even if it adjusts the thickness of a buffer coat. It is in the 1st Lynn-ized boron system semi-conductor layer containing silicon, and it is suitable for the atomic concentration of the silicon in a layer to carry out to under the concentration of the Lynn (P) atom which occupies the hole (vacancy) of boron, or the boron (B) atom which occupies the hole in Lynn. Also although it says that ******** and silicon work as an amphoteric by maintaining the relation of this concentration, the predominance of the Lynn-ized boron system semi-conductor which can obtain the semi-conductor layer of the conduction type of the both sides of n form or p form simple is maintainable in the state of undoping.
[0017] the -- even if it is in the 1st Lynn-ized boron system semi-conductor layer which contains carbon (C) as an IV group element, the carbon atom concentration in a layer depends on adjustment of membrane formation temperature, and can be controlled. Carbon atom concentration in a layer can be made into high concentration, so that membrane formation temperature, i.e., the retention temperature of a silicon single crystal substrate, is made into an elevated temperature. However, at the elevated temperature exceeding 1200 degrees C, the Lynn-ized boron crystal of the polymer of B6P of the rhombohedron crystal structure or B13P2 grade becomes is easy to be formed about membrane formation temperature, and it becomes inconvenient for obtaining the Lynn-ized boron system semi-conductor layer homogeneous in presentation. Moreover, the carbon concentration in the 1st Lynn-ized boron system semi-conductor layer can be made into high concentration, so that it makes the concentration into the membrane formation environment of the organic boron compound of the source slack above of (Boron B) to supply increase. However, it is in the 1st Lynn-ized boron system semi-conductor layer containing carbon, and it is suitable for the atomic concentration of the carbon in a layer to carry out to under the concentration of the Lynn (P) atom which occupies the hole (vacancy) of boron, or the boron (B) atom which occupies the hole in Lynn. Also although it says that ******** and carbon work as an amphoteric by maintaining the relation of this concentration, the 1st conduction type concluded in the state of undoping is maintainable. the concentration of the boron atom which occupies the Lynn hole, or the concentration of the Lynn atom which occupies a boron hole -- as each, the concentration of boron-boron (B-B) association, or the concentration of the Lynn-Lynn (P-P) association -- the Raman (Raman) spectroscopy and nuclear magnetic resonance (NMR) -- it depends on means, such as law, and can measure.
[0018] The luminous layer which consists of a group III-V semiconducter concerning the 1st operation gestalt of this invention can consist of III group nitride semi-conductor layers, such as for example, a gallium nitride indium (GaXIn1-XN:0 <=X<=1) and a phosphorus nitride-ized gallium (GaN1-YPY:0 <=Y<=1). especially -- the [for example,] -- the III group nitride semi-conductor layer which added IV group element intentionally (doping) can be suitably used as a luminous layer. Silicon (Si), carbon (C), etc. can be illustrated to the impurity doped to a luminous layer. especially -- silicon -- the [other] -- since it is hard to be spread upwards to the exterior of a luminous layer as compared with germanium (germanium) and tin (Sn) which are IV group element and can dope easily as compared with the case of carbon (C), it can use suitably. the [inside a luminous layer] -- the suitable concentration of IV group element is 1x1019 atom / [1x1017 atom / cm3 -] cm3 in general. They are especially suitable abbreviation 5x1018 atom / cm3 - abbreviation 7x1018 atom / cm3. 1x1019 atom / cm3 is exceeded -- as -- the -- in the luminous layer which doped IV group element, crystallinity gets worse and it does not come to obtain the luminous layer which brings about luminescence of high intensity. Let conduction type of a luminous layer be the 1st or 2nd conduction type. In the case of the luminous layer of the 2nd conduction type, junction in the 1st Lynn-ized boron system semi-conductor layer of the 1st conduction type can constitute single hetero (single hetero:SH) assembling-die pn junction structure. Moreover, the light-emitting part of double hetero (double hetero: English abbreviated name DH)

structure including the pn junction structure of the configuration which is made to join the 2nd Lynn-ized boron system semi-conductor layer of the 2nd conduction type mentioned later to the luminous layer of the 1st conduction type, and is prepared in it, then the luminous layer and the 2nd Lynn-ized boron system semi-conductor layer can be built. As an example of the 4th operation gestalt of this invention, the 1st Lynn-ized boron system semi-conductor layer is used as the Lynn-ized boron and the gallium (BXGa1-XP:0.5 <=X<=1) layer of undoping containing silicon, silicon is doped, and the case where a luminous layer is constituted from a phosphorus nitride-ized gallium (GaN1-YPY:0 <=Y<=1) which set atomic concentration of silicon to 2x1017 atom / cm3 can be raised.

[0019] A luminous layer can consist of single quantum well structure (SQW) or multiplex quantum well structure (MQW). If it is in the quantum well structure of using the tunnel (tunnel) effectiveness of a carrier (carrier), an obstruction (barrier) layer thicker than a well (well) layer also needs to consist of thin films. Before membrane formation, beforehand, the luminous layer of the quantum well structure which consists of continuous thin films uses the growth furnace which made the coat containing boron (B) and Lynn (P) put on a wall, and the Lynn-ized boron system semi-conductor layer which formed membranes on the silicon single crystal substrate is obtained as a substrate. Emission of the matter which pollutes the front face of the silicon single crystal substrate which makes the origin the decomposition product adhering to a fission reactor wall or a wall is controlled, the above-mentioned coat acts effective in obtaining the Lynn-ized boron system semi-conductor layer which is excellent in surface surface smoothness and a surface continuity, and if spread, it becomes convenient for forming the luminous layer which is excellent in surface surface smoothness and a surface continuity.

[0020] If it is the laminating configuration prepared on the 1st [of the thickness which has 30% or more of reflection factor] Lynn-ized boron system semi-conductor layer to the light which sets wavelength to lambda for the luminous layer which carries out outgoing radiation of the light which sets wavelength to lambda, since it will depend on the 1st Lynn-ized boron system semi-conductor layer and luminescence from [a part of] a luminous layer will be reflected, it is constituting LED which is excellent in the ejection effectiveness of luminescence to the component exterior with dominance. For example, the laminating configuration which prepares the luminous layer which emits the purple-blue light which sets wavelength to 420nm on the 1st Lynn-ized boron semi-conductor layer which sets thickness to about 300nm can be illustrated. When it constitutes the 1st Lynn-ized boron system semi-conductor layer from Lynn-ized boron (BP) of a monomer, the relation of the relational expression (1) of degree account between luminescence of wavelength lambda (unit nm;420 <=lambda<=490) and the thickness (unit: nm) of the 1st Lynn-ized boron system semi-conductor layer which can give 30% or more of reflection factor to it is.

lambda**0.135-d+380 ... Relational expression (1)

[0021] In the 5th operation gestalt of this invention, the 2nd Lynn-ized boron system semi-conductor layer of the 2nd conduction type formed on the above-mentioned luminous layer consists of Lynn-ized boron system semi-conductor layers of undoping. The 2nd Lynn-ized boron system semi-conductor layer consists of BalphaaluminumbetaGagammaIn1-alpha-beta-gamma P1-deltaAsdelta (0< alpha<=1, 0<=beta<1, 0<=gamma<1, 0< alpha+beta+gamma <=1, 0<=delta<1) as well as the case of the 1st Lynn-ized boron system semi-conductor layer. Moreover, for example, it can constitute from BalphaaluminumbetaGagammaIn1-alpha-beta-gamma P1-deltaNdelta (0< alpha<=1, 0<=beta<1, 0<=gamma<1, 0< alpha+beta+gamma <=1, 0<=delta<1). The 2nd Lynn-ized boron system semi-conductor layer is a semi-conductor layer which sandwiches a luminous layer, counters the 1st above-mentioned Lynn-ized boron system semi-conductor layer, and is prepared. Moreover, it is a conductive semi-conductor layer for pinching the 1st Lynn-ized boron system semi-conductor layer and luminous layer, and constituting the light-emitting part of pn junction mold DH structure. The conduction type of the 2nd Lynn-ized boron system semi-conductor layer presupposes that it is contrary to the silicon single crystal and the 1st Lynn-ized boron system semi-conductor layer which make a substrate. For example, let the 2nd Lynn-ized boron system semi-conductor layer be n form layer to the {111}-Si single crystal of p form, and the 1st Lynn-ized boron system semi-conductor layer of p form.

[0022] especially -- a presentation (=alpha) and Lynn of boron (B) -- the boron and Lynn which carry out each presentation (=1-delta) of (P) to more than 0.5 (= 50%) are included as a subject -- for example BalphaaluminumbetaGagammaIn1-alpha-beta-gamma P1-deltaAsdelta (0.5<=alpha<=1, 0<=beta<0.5, 0<=gamma<0.5, 0.5< alpha+beta+gamma <=1, 0<=delta<0.5), Or it can constitute from BalphaaluminumbetaGa</SUB>gamma In1-alpha-beta-gamma P1-deltaNdelta (0.5<=alpha<=1, 0<=beta<0.5, 0<=gamma<0.5, 0.5< alpha+beta+gamma <=1, 0<=delta<0.5) suitably. From the Lynn-ized boron system semi-conductor mixed crystal which contains Lynn-ized boron (B) and Lynn (P) actively, there is an advantage to which the impurity which controls conduction type is not added intentionally (= doping), but the Lynn-ized boron system semi-conductor layer of the conductivity [**] of the 2nd conduction type is brought. That is, there is an advantage which can obtain the Lynn-ized boron system semi-conductor layer of the 2nd conduction type simple by undoping.

[0023] While the doping actuation accompanied by modification of an impurity kind be avoidable, there be an advantage from which the conductive layer of low resistance be easily obtain by high carrier concentration in constituting the 1st and 2nd Lynn-ized boron system semi-conductor layers from an undoping layer by changing the relative rate of the ratio of concentration of the donor (donor) who participate in the hole of boron (B) or Lynn (P), or an acceptor (acceptor) component. For example, even if it is undoping, n form Lynn-

ized boron system semi-conductor layer of low resistance which makes it carrier concentration and exceeds abbreviation 5x1018cm-3 can be obtained. Moreover, if it is undoping, p form Lynn-ized boron system semi-conductor layer of low resistance of the carrier concentration exceeding abbreviation 1x1019cm-3 can be constituted simple. the [for example, /, such as sulfur (S) or a selenium (Se),] -- it is [that the semi-conductor layer which a front face has and lacks in a continuity is only brought about by addition of rather a lot of / that it is difficult to be stabilized and to discover concentration of electrons high like the case of the above-mentioned undoping in the place which doped n form impurity of VI group element so much, and / impurities, and]. [disorderly] the [moreover,] -- the front face disorderly in the place which doped so much p form impurity nature which cannot form boron (B) and compounds, such as zinc (Zn) of II group element, and cadmium (Cd), easily which may not come to be stabilized in the Lynn-ized boron system semi-conductor layer of low resistance of the above-mentioned high electron hole concentration -- discontinuity -- it is [that a semi-conductor layer is only concluded and]. That is, even when obtaining the Lynn-ized boron system semi-conductor layer of which conduction type of n form or p form, a best policy depends on the undoping means which does not add an impurity intentionally.

[0024] The conduction type of the Lynn-ized boron system semi-conductor layer of undoping can adjust and control membrane formation temperature. The membrane formation temperature suitable for obtaining the undoping phosphorus-ized boron system semi-conductor layer of n form is 750 degrees C - 950 degrees C about. It is about 1000 degrees C - about 1200 degrees C that it is suitable for on the other hand obtaining p form Lynn-ized boron system semi-conductor layer of undoping. Especially, the range of about 1025 degrees C - about 1100 degrees C is suitable. The Lynn-ized boron system semi-conductor layer which formed membranes at the elevated temperature exceeding about 1000 degrees C, and especially the Lynn-ized boron (boron monophosphide) layer of the monomer containing the twin crystal (twinning) which makes the {111}-crystal face a twin boundary side can be suitably used as 1st or 2nd Lynn-ized boron system semi-conductor layer. The twin crystal contained inside a layer can contribute for bringing about the Lynn-ized boron system semi-conductor layer which eases the mistake mitt (misfit) of a grid with a luminous layer etc., and is excellent in crystallinity. the [moreover, /, such as boron (B) supplied to the membrane formation system of reaction,] -- Lynn to the concentration of the sum total an III group's configuration element -- the ratio of the concentration of the sum total of the Vth group configuration elements, such as (P), and the so-called V/III ratio also affect control of conduction type. n form Lynn-ized boron system semi-conductor layer of undoping becomes is easy to be obtained, so that a V/III ratio is made into a high ratio, when membrane formation temperature is made the same.

[0025] the 6th operation gestalt of this invention -- setting -- the 2nd Lynn-ized boron system semi-conductor layer -- the -- IV group element consists of Lynn-ized boron system semi-conductor layers of the 2nd conduction type added intentionally. The 2nd Lynn-ized boron system semi-conductor layer is arranged to the silicon single crystal substrate in the remoteness location rather than the 1st Lynn-ized boron system semi-conductor layer. For this reason, as compared with the case of the 1st Lynn-ized boron system semi-conductor layer, the concentration of the silicon atom which diffuses the silicon single crystal of a substrate as the origin is in the situation which decreases. for this reason, the case of the 1st Lynn-ized boron system semi-conductor layer -- differing -- the [to the 2nd Lynn-ized boron system semi-conductor layer] -- the [with the above suitable for addition of IV group element] -- it becomes a means convenient for obtaining the atomic concentration of IV group element. the [to add] -- in IV group element, carbon (C), silicon (Si), germanium (germanium), and tin (Sn) can be illustrated. In the carbonaceous source of addition, carbon content compounds, such as methane (CH4), trimethyl phosphorus (CH3) (3P), and carbon tetrabromide (CBr4), can be illustrated. In the source of doping of silicon, silicon content gases, such as a silane (SiH4) and a disilane (Si2H6), can be illustrated.

[0026] since the conductive layer of high carrier concentration has already been obtained like the above in the state of undoping even if it does not add n form or p form impurity -- here -- the -- adding IV group element in order to control the conduction type of the 2nd Lynn-ized boron system semi-conductor layer -- if -- there is nothing. the [which was added to the luminous layer to the last] -- diffusion inside the 2nd Lynn-ized boron system semi-conductor layer of IV group element -- controlling -- the [in a luminous layer] -- it is for maintaining the atomic concentration of IV group element to the concentration for bringing about luminescence of high intensity. the -- IV group element is made below into the concentration of the Lynn atom which occupies the boron hole which governs the conduction type of the 2nd Lynn-ized boron system semi-conductor layer, or the boron atom which occupies the Lynn hole. the concentration of the donor in whom the hole participated, or an acceptor component -- exceeding -- abundant -- the -- even if it adds IV group element, it is [that the 2nd Lynn-ized boron system semi-conductor layer by which surface surface smoothness was spoiled is only concluded, and].

[0027] the [which is contained in the 2nd Lynn-ized boron system semi-conductor layer with the 7th operation gestalt of this invention] -- the [which is added to IV group element and a luminous layer] -- IV group impurity is made the same. the [which is made to exist in a luminous layer and the 2nd Lynn-ized boron system semi-conductor layer] -- the [by making IV group element the same / between both layers] -- the counter diffusion of IV group element can be controlled. the [furthermore, / in both layers] -- the atomic concentration of IV group element -- abbreviation -- the [equivalent, then] -- the diffusion to the 2nd Lynn-ized boron system semi-conductor layer from the luminous layer of IV group element -- effectiveness can be

raised more for controlling the both sides of the diffusion to a luminous layer from the 2nd Lynn-ized boron system semi-conductor layer conversely. a luminous layer and the 2nd Lynn-ized boron system half conductor layer -- the [in ** and a layer] -- the atomic concentration of IV group element -- the -- it can adjust with the amount of doping of IV group element. the -- the [which was chosen so that the criteria with which the atomic concentration of IV group element should be doubled may obtain luminescence of high intensity to the last / of a luminous layer] -- it is the atomic concentration of IV group element. the [of the 1st or 2nd Lynn-ized boron system semi-conductor layer] -- the case where the atomic concentration of IV group element is not in agreement with the optimal atomic concentration of a luminous layer -- the [in the 1st and 2nd Lynn-ized boron system semi-conductor layers] -- it is desirable to adjust the atomic concentration of IV group element to less than **30% in a difference on the basis of the optimal concentration of a luminous layer. the [furthermore, / of the 1st and 2nd Lynn-ized boron system semi-conductor layers] -- making the atomic concentration of IV group element agree in it of a luminous layer -- the -- the counter diffusion of IV group element is controlled and it becomes the most convenient for obtaining the luminous layer which gives luminescence of high intensity.

[0028] the [moreover, / between a luminous layer and the 2nd Lynn-ized boron system semi-conductor layer], so that the difference in the atomic concentration of IV group element is size -- the [between a luminous layer and the 2nd Lynn-ized boron system semi-conductor layer] -- diffusion of IV group element becomes remarkable. the [therefore, / of the 2nd Lynn-ized boron system semi-conductor layer] -- the atomic concentration of IV group element -- the [of a luminous layer] -- it is optimal that it is the same as that of the atomic concentration of IV group element. at least -- the [of a luminous layer] -- it is desirable that it is the atomic concentration which is in **30% of range to the concentration of IV group element. There is an example to which the 2nd Lynn-ized boron system semi-conductor layer which consists of a Lynn-ized boron layer of n form where silicon atom concentration was adjusted in 3x1018 atom / cm3 as a good example of the 8th operation gestalt of this invention about n form luminous layer which sets silicon atom concentration to 3x1018 atom / cm3 is joined. the interior of the 2nd Lynn-ized boron system semi-conductor layer -- especially -- the [in the direction of thickness], so that distribution of the atomic concentration of IV group element is made uniform -- the [from the luminous layer to the 2nd Lynn-ized boron system semi-conductor layer] -- effectiveness can be raised for controlling diffusion of IV group element. The 1st and 2nd Lynn-ized boron system semi-conductor layers which are different in the conduction type which pinches a luminous layer moreover, with the same ingredient and the distorted amount impressed [of a luminous layer] from the upper and lower sides by constituting from a semi-conductor layer of the same thickness to a luminous layer -- the [from equal, then the luminous layer to the 1st and 2nd Lynn-ized boron system semi-conductor layers] -- effect is taken more by controlling diffusion of IV group element.

[0029] the [which makes a luminous layer exist in the 2nd Lynn-ized boron system semi-conductor layer list with the 9th operation gestalt of this invention] -- let IV group element be silicon (Si). silicon -- the -- it is the element of difficulty diffusibility also in IV group element, for example, becomes convenient for controlling the diffusion to a luminous layer from the 2nd Lynn-ized boron system semi-conductor layer. Furthermore, the 2nd Lynn-ized boron system semi-conductor layer of the silicon atom concentration which makes a difference smallness within **30% on the basis of the atomic concentration of the silicon of a luminous layer inhibits diffusion of the silicon atom to a luminous layer, and becomes still more effective in maintaining the silicon atom concentration in a luminous layer the optimal. as for example, the example of 1 configuration -- silicon atom concentration -- about -- the n form GaXIn1-XN (0<=X<=1) luminous layer set to 4x1018 atom / cm3, and silicon atom concentration -- about -- there is heterojunction structure with the 1st and 2nd Lynn-ized boron (BP) layers set to 5x1018 atom / cm3.

[0030] Temporarily, when the 1st conduction type is made into p form, undoping can constitute the 1st Lynn-ized boron system semi-conductor layer from the Lynn-ized boron (BP) layer of p form. The boron atom which works as an acceptor component and which occupies the Lynn hole exists in p form Lynn-ized boron (BP) of undoping so much. Therefore, it does not come to decrease very the electron hole (hole) concentration of an undoping p form Lynn-ized boron (BP) layer, therefore conduction type does not change in the place which made p form Lynn-ized boron (BP) layer of undoping which makes the 1st Lynn-ized boron system semi-conductor layer contain a silicon atom like the above by less than [1018cm - 3-1019cm -] three atomic concentration. On the other hand, the 1st conduction type is made into n form, and when it constitutes the 1st Lynn-ized boron system semi-conductor layer from n form Lynn-ized boron (BP) of undoping, even if it is, the Lynn atom which occupies the boron hole of a donor component exists in the n form BP layer of undoping by the high concentration exceeding the double [about] figures silicon atom of less than [1018cm - 3-1019cm -] three concentration. Therefore, a lot of donors in whom the hole participated cannot be compensated electrically enough in the place where the silicon which is ******** and an amphoteric acted as an acceptor (compensate), but the conduction type of the 1st Lynn-ized boron system semi-conductor layer is maintained by n form. therefore -- the 10th operation gestalt of this invention -- the -- the 1st and 2nd Lynn-ized boron system semi-conductor layers are constituted as below the concentration of the donor in whom the above-mentioned hole participates the atomic concentration of IV group element, or an acceptor component. in order to compensate electrically the donor or acceptor in which these holes participate -- the -- in the place which doped IV group element so much, a lot of doping beyond whenever [dissolution] will be performed, and it originates in the appearance of the sludge containing a dopant etc., is coarse, and is [that

the Lynn-ized boron system semi-conductor layer which lacks in surface smoothness is only brought about, and]. The Lynn-ized boron system semi-conductor layer of undoping can constitute the Lynn-ized boron system semi-conductor layer of low resistance for [which receives a luminous layer], for example, constituting an obstruction (clad) layer most suitably and simple so that this invention may describe.
[0031]
[Function] the [which contains conduction type in the 1st and 2nd different Lynn-ized boron system semi-conductor layers] -- the [by which IV group element was intentionally added by the luminous layer (doping)] -- the operation which controls the 1st of IV group element, and the diffusion to the 2nd Lynn-ized boron system semi-conductor layer -- having -- the [inside a luminous layer] -- it has the operation which brings about luminescence of high intensity for the atomic concentration of IV group element and which boils and maintains to the optimal concentration.
[0032] the [which is contained in the 1st and 2nd Lynn-ized boron system semi-conductor layers] -- without the silicon as an IV group element changes the conduction type of the 1st and 2nd Lynn-ized boron system semi-conductor layers in an undoping condition -- the [more effective in controlling the atomic diffusion to a luminous layer, or diffusion of the hard flow than both layers] -- it acts as an IV group element kind.
[0033]
[Example] (The 1st example) The 1st conduction type of a publication in the text is made into n form, the case where the Lynn-ized boron system semi-conductor LED is constituted using the 1st Lynn-ized boron system semi-conductor layer of n form and the 2nd Lynn-ized boron system semi-conductor layer of p form is made into an example by making the 2nd conduction type into p form, and this invention is explained concretely.
[0034] The mimetic diagram of LED1B concerning the 1st example is shown in drawing 1 . Moreover, the cross section of LED1B in alignment with broken-line X-X' shown in drawing 1 is shown in drawing 2 .
[0035] Laminating structure 1A of an LED1B application formed the n form Si single crystal of the antimony (Sb) dope which uses the crystal face (111) as a front face as a substrate 101. a substrate 101 top -- boron triethyl (C2H5) (3B) / phosphine (PH3) / hydrogen (H2) system ordinary pressure MOCVD -- the buffer coat 102 which consists of Lynn-ized boron which makes an amorphous substance a subject in the state of as-grown at 350 degrees C by law was deposited. The thickness of a buffer coat 102 could be 5nm.
[0036] After ending membrane formation of a buffer coat 102, the temperature of a substrate 101 was raised at 1050 degrees C. The laminating of the 1st Lynn-ized boron system semi-conductor layer 103 which sets to about 330nm thickness which consists of an n form Lynn-ized boron (BP) layer of undoping on the front face of a buffer coat 102 was carried out after the temperature up using the above-mentioned MOCVD vapor growth means. After ending membrane formation of the 1st Lynn-ized boron system semi-conductor layer 103 of the 1st conduction type (the 1st example n form), in 1050 degrees C, this layer is held for 10 minutes within the ambient atmosphere which mixed a phosphine (PH3) and hydrogen (H2). The incorporation by the interior of the 1st Lynn-ized boron system semi-conductor layer 103 of the silicon atom diffused from the silicon single crystal substrate 101 was urged. a general secondary ion mass spectrometry (SIMS) -- depending -- the silicon atom concentration inside the 1st Lynn-ized boron system semi-conductor layer 103 -- about 4 -- the quantum was carried out to x1018cm-3. The carrier concentration of the 1st Lynn-ized boron system semi-conductor layer 103 was abbreviation 8x1018cm-3. Moreover, the band gap in the room temperature of BP layer of the monomer which makes the 1st Lynn-ized boron system semi-conductor layer 103 was called for with about 3.0eV from the photon energy dependency of the product value (=2 and eta-kappa) of a refractive index (eta) and an extinction coefficient (kappa).
[0037] the 1st Lynn-ized boron system semi-conductor layer 103 top -- trimethylgallium (CH3) (3Ga) / trimethylindium (CH3) (3In) / ammonia (NH3) / H-2 system ordinary pressure MOCVD -- in 850 degrees C, the laminating of the luminous layer 104 which consists of a gallium nitride indium (Ga0.94In0.06N) of n form was carried out by law. At the time of membrane formation of a luminous layer 104, disilane (Si2H6)-hydrogen (H2) mixed gas was used, and silicon (Si) was doped at it. The amount of doping of the silicon to a luminous layer 104 was set up so that the silicon atom concentration in this layer 104 might be set to abbreviation 5x1018cm-3. The thickness of a luminous layer 104 could be 50nm.
[0038] On the front face of a luminous layer 104, the laminating of the 2nd Lynn-ized boron system semi-conductor layer 105 which consists of Lynn-ized boron (BP) of p form which is the 2nd conduction type was carried out. the 3 B/PH3/H-2 system ordinary pressure MOCVD as the case of the 2nd Lynn-ized boron system semi-conductor layer with the 2nd same (C2H5) Lynn-ized boron system semi-conductor layer 105 of the 2nd conduction type (the 1st example p form) -- membranes were formed at 850 degrees C by law. the atomic concentration of the silicon which remains in this layer 105 at the time of membrane formation of the 2nd Lynn-ized boron system semi-conductor layer 105 (residual) -- about 2 -- although it is x1017cm-3 -- taking an example -- total silicon atom concentration -- about 4 -- silicon was doped using disilane-hydrogen mixed gas so that it might be set to x1018cm-3. Carrier concentration of the 2nd Lynn-ized boron system semi-conductor layer 105 was set to abbreviation 1x1019cm-3. Thickness could be about 330nm as well as the 1st Lynn-ized boron system semi-conductor layer 103. The 2nd Lynn-ized boron system semi-conductor layer 105 as well as the 1st Lynn-ized boron system semi-conductor layer 103 consisted of Lynn-ized boron (BP) of the monomer which sets the band gap in a room temperature to about 3.0eV.
[0039] The light-emitting part of a pn junction mold double heterojunction (DH) structured type consisted of the 1st and 2nd Lynn-ized boron system semi-conductor layers 103 and 105 which are different in conduction

type, and a luminous layer 104. The quantum result of the silicon atom concentration of the depth direction of each configuration layers 103-105 which constitute the light-emitting part which depends on SIMS analysis general to drawing 3 is shown. The silicon atom concentration of the 1st and 2nd Lynn-ized boron system semi-conductor layers 103 and 105 became about 0.8 times on the basis of the silicon atom concentration of a luminous layer 104. That is, as compared with the silicon atom concentration of a luminous layer 104, it became low concentration about 20%. Moreover, as shown in drawing 3 , it was admitted in the depth direction (the direction of thickness) of each configuration layers 103-105 that the silicon atom was distributed over Mr. abbreviation 1. The 1st and 2nd Lynn-ized boron system semi-conductor layers 103 and 105 which pinch a luminous layer 104 in that balance was maintained at silicon atom concentration in the internal luminous layer 104, 1st, and 2nd Lynn-ized boron system semi-conductor layers 103 and 105, and a list by the same matter And since it constituted from a semiconductor material (= BP) of the same thickness, it was judged that diffusion of the silicon atom from the luminous layer 104 to the 1st or 2nd Lynn-ized boron system semi-conductor layer 103 and 105 or the diffusion to the hard flow was controlled.
[0040] The surface electrode 106 which consists of three-layer multistory structure of Au-Zn / (nickel nickel) / gold (Au) which has arranged the ohmic (Ohmic) electrode which becomes a side in contact with this layer 105 from gold and a zinc (Au-Zn) alloy was formed in the center section of the front face of the 2nd Lynn-ized boron system semi-conductor layer 105 of p form. The surface electrode 106 which serves as the plinth (pad) electrode for connection was used as the circular electrode which sets a diameter to about 120 micrometers. Moreover, all over the abbreviation for the rear face of the n form Si single crystal substrate 101, the ohmic electrode which consists of an aluminum antimony (aluminum-Sb) alloy as a rear-face electrode 107 has been arranged, and LED1B was constituted. The thickness of the aluminum-Sb vacuum evaporationo film could be about 2 micrometers. After forming a front face and the rear-face electrodes 106 and 107, Si single crystal which forms a substrate 101 was cut out in the direction parallel to the [211] directions, and perpendicular, and it was referred to as LED1B of the square which sets one side to about 350 micrometers.
[0041] When conduction of the operating current of 20mA (mA) was carried out between a surface electrode 106 and the rear-face electrode 107 in the forward direction, the violet band light which sets wavelength to about 430nm from LED1B was emitted. The brightness in the chip (chip) condition measured using a common integrating sphere became a 9mm candela (mcd), and LED1B of high luminescence reinforcement was offered. moreover, forward voltage (Vf, however forward current = 20mA) -- about 3 -- it is V and reverse voltage (VR, however reverse current =10microA) became more than 5V. From this good rectifying characteristic, it was taught that disorderly-ization of the heterojunction interface based on diffusion of the silicon atom between the luminous layer 104, 1st, and 2nd Lynn-ized boron system semi-conductor layers 103 and 105 is inhibited (refer to the work edited by the opto-electronics common lab, "the basic technique of an optoelectronic integrated circuit" (August 20, 1989, Ohm-Sha Issue, the 1st edition 1st **), and 371 - 384 pages).
[0042] (The 2nd example) The 1st conduction type is made into p form, the case where the Lynn-ized boron system semi-conductor LED is constituted using the 1st Lynn-ized boron system semi-conductor layer of p form and the 2nd Lynn-ized boron system semi-conductor layer of n form is made into an example by making the 2nd conduction type into n form, and this invention is explained concretely.
[0043] The cross section of LED2B concerning **** 2 example is shown in drawing 4 . In laminating structure 2A shown in drawing 4 , the same sign as drawing 1 or drawing 2 is attached about the same component as laminating structure 1A illustrated to drawing 1 and drawing 2 .
[0044] Laminating structure 2A of an LED2B application formed the p form Si single crystal of the boron (B) dope which uses the crystal face (111) as a front face as a substrate 101.
[0045] the front face of a substrate 101 -- the 3 (C2H5) B/PH3/H-2 system reduced pressure MOCVD -- it depended on law and the laminating of the 1st Lynn-ized boron system semi-conductor layer 103 which consists of a p form Lynn-ized boron (BP) layer by undoping at 1075 degrees C was carried out. The pressure at the time of membrane formation was held in about 0.2 atmospheric pressures. the silicon atom which invades from the silicon single crystal substrate 101 while [15 minutes] achieving membrane formation of the 1st Lynn-ized boron system semi-conductor layer 103 of the 1st conduction type (the 2nd example p form), and is diffused -- being based -- the silicon atom concentration inside a layer 103 -- about 7 -- it amounted to x1018cm-3. even if silicon atom concentration turns into such high concentration -- considering the sense of thermoelectromotive force -- ("semiconductor technology (above)" of a publication in the text, refer to 119 - the 120 page), and this layer 103 -- the conductivity of p form -- maintaining -- **** -- the carrier concentration -- about 2 -- it is checked separately that it is x1019cm-3. Moreover, the thickness of the 1st Lynn-ized boron system semi-conductor layer 103 could be about 210nm. The band gap in the room temperature of BP layer of the monomer which makes the 1st Lynn-ized boron system semi-conductor layer 103 was about 3.0eV.
[0046] since [moreover,] the 1st Lynn-ized boron system semi-conductor layer 103 set the rate of a supply quantitative ratio (= PHs 3/(C2H5) 3B) with PHs 3 and 3 (C2H5)B to the MOCVD system of reaction to 90 and the membrane formation rate was formed as a part for 30nm/-- the interior -- twin crystal 108 -- abbreviation -- it became what is included by the uniform consistency. Twin crystal 108 was what makes the {111}-crystal face of Lynn-ized boron (BP) a twin boundary side. Although it could consider that twin crystal

was also a kind of stacking fault (stacking fault) (refer to hill ******, "crystal electron microscope study" (November 25, 1997, the 1st Edition of Uchida Rokakuho Publishing Issue), and 111 - 112 pages), it did not come to distinguish clearly which stacking fault (refer to the above-mentioned "crystal electron microscope study" and 141 pages) of a format of an in thorin chic (intrinsic) mold or an EKUSU thorin chic (extrinsic) mold.

[0047] the 1st Lynn-ized boron system semi-conductor layer 103 top -- the 3(CH3) Ga/(CH3)3 In/NH3/H-2 system reduced pressure MOCVD -- by law, it was alike, it set at 800 degrees C, and the laminating of the luminous layer 104 which consists of an n form gallium nitride indium (Ga0.90In0.10N) which doped Si was carried out. The luminous layer 104 formed membranes under reduced pressure of about 0.8 atmospheric pressures. Thickness could be about 50nm. At the time of membrane formation of a luminous layer 104, Si2H6-H2 mixed gas was used, and silicon was doped at it so that the silicon atom concentration in a layer might be set to abbreviation 7x1018cm-3. The above-mentioned silicon element concentration inside the 1st Lynn-ized boron system semi-conductor layer 103 is more nearly extraordinarily [than the concentration of the boron (B) atom which occupies the Lynn (P) hole] low, and the front face of this layer 103 came to excel in surface smoothness. For this reason, the front face of the luminous layer 104 formed on the 1st Lynn-ized boron system semi-conductor layer 103 does not have a projection, either, and became flat.

[0048] On the front face of a luminous layer 104, the laminating of the 2nd Lynn-ized boron system semi-conductor layer 105 which consists of Lynn-ized boron (BP) of n form was carried out. the time of membrane formation of the 2nd Lynn-ized boron system semi-conductor layer 105 of the 2nd conduction type (the 2nd example n form) -- the residual concentration of the silicon atom in this layer 105 -- about 4 -- although it is x1017cm-3 -- taking an example -- total silicon atom concentration -- about 7 -- silicon was doped using disilane-hydrogen mixed gas so that it might be set to x1018cm-3. This silicon atom concentration was farther [than the concentration of the Lynn (P) atom which occupies the hole of boron (B)] low, therefore reversal of the conduction type of the 2nd Lynn-ized boron system semi-conductor layer was not accepted. Moreover, by such silicon atom concentration, generating of the sludge containing silicon was not accepted but became the continuation film which has the flat front face of the 2nd Lynn-ized boron system semi-conductor layer 105. Carrier concentration of the 2nd Lynn-ized boron system semi-conductor layer 105 was set to abbreviation 1x1019cm-3. Thickness could be about 210nm as well as the 1st Lynn-ized boron system semi-conductor layer 103. The 2nd Lynn-ized boron system semi-conductor layer 105 consisted of Lynn-ized boron (BP) of the monomer which sets the band gap in a room temperature to about 3.0eV. The light-emitting part of a pn junction mold double heterojunction (DH) structured type consisted of the 1st and 2nd Lynn-ized boron system semi-conductor layers 103 and 105 which are different in conduction type, and a luminous layer 104.

[0049] The surface electrode 106 has been arranged in the center section of the front face of the 2nd Lynn-ized boron system semi-conductor layer 105 of n form. The surface electrode 106 constituted the side in contact with the 2nd Lynn-ized boron system semi-conductor layer 105 from three layer multistory film of Au-germanium/nickel/Au used as gold and the germanium (Au-germanium) alloy film. The diameter of the circular surface electrode 106 which serves as a plinth electrode was set to about 110 micrometers. All over the abbreviation for the rear face of the p form Si single crystal substrate 101, the ohmic electrode which consists of aluminum (aluminum) as a rear-face electrode 107 has been arranged, and LED2B was constituted. The thickness of aluminum vacuum deposition film could be about 3 micrometers. After forming a front face and the rear-face electrodes 106 and 107, the Si single crystal 101 was cut out in the direction parallel to the [211] directions, and perpendicular, and it considered as LED2B of the square which sets one side to about 350 micrometers.

[0050] The emission center wavelength at the time of carrying out conduction of the operating current of 20mA (mA) between a surface electrode 106 and the rear-face electrode 107 in the forward direction was set to about 440nm. Silicon atom concentration of a luminous layer 104 and the 1st [of a barrier layer] and 2nd Lynn-ized boron system semi-conductor layers 103 and 105 was made the same, since fluctuation of the silicon atom concentration in the luminous layer 104 based on diffusion was inhibited, the brightness in the chip (chip) condition measured using a common integrating sphere became an about 10mm candela (mcd), and LED2B of high luminescence reinforcement was offered. moreover, the forward voltage (= Vf) for which the good rectifying characteristic was demonstrated and it asked from the current-electrical-potential-difference (I-V) property -- about 3 -- it was V (however, forward current = 20mA), and reverse voltage is 7V (however, reverse current =10microA), and LED2B which is also high pressure-proofing was offered.

[0051]

[Effect of the Invention] the [which will be prepared on the substrate which consists of a silicon single crystal, and will bring about luminescence of high intensity if it depends on this invention / which was alike and was added by the optimal atomic concentration] -- to the luminous layer which consists of an III-V group semi-conductor containing IV group element the, since the 1st and 2nd Lynn-ized boron system semi-conductor layers which are different in conduction type including IV group element are joined and pn junction mold heterojunction structure is constituted the [for example, / from a luminous layer] -- external diffusion of IV group element -- controlling -- effectiveness -- doing so -- the [in a luminous layer] -- the atomic concentration of IV group element can be maintained from a viewpoint of luminescence reinforcement to the optimal concentration, and the light emitting device of high luminescence reinforcement can be offered.

[0052] The 1st [which pinches a luminous layer and makes heterojunction structure by this invention

especially], or 2nd Lynn-ized boron system semi-conductor layer a luminous layer and abbreviation -- the [equivalent], since it constitutes from a conductive semi-conductor layer of the 1st or 2nd conduction type which has the atomic concentration of IV group element the [resulting from the difference in atomic concentration] -- effectiveness is raised for controlling the counter diffusion of IV group element -- having -- the [in a luminous layer] -- the atomic concentration of IV group element can be maintained from a viewpoint of luminescence reinforcement to the optimal concentration, and the light emitting device of high luminescence reinforcement is brought about -- it can be alike and can contribute.
[0053] Moreover, the 1st [which pinches luminescence and makes heterojunction structure by this invention especially], or 2nd Lynn-ized boron system semi-conductor layer the [as what was doped to the luminous layer / same], since it constitutes from a conductive semi-conductor layer of the 1st or 2nd conduction type containing IV group element the [resulting from the difference in atomic concentration] -- effectiveness is further raised for controlling the counter diffusion of IV group element -- having -- the [in a luminous layer] -- the atomic concentration of IV group element can be maintained from a viewpoint of luminescence reinforcement to the optimal concentration, and the light emitting device of high luminescence reinforcement can be brought about.
[0054] Moreover, the 1st [which pinches luminescence and makes heterojunction structure by this invention especially], or 2nd Lynn-ized boron system semi-conductor layer the [as what was doped to the luminous layer / same] -- IV group element -- abbreviation, since it constitutes from a conductive semi-conductor layer of the 1st or 2nd conduction type included by the same atomic concentration the [resulting from the difference in atomic concentration] -- effectiveness is further raised for inhibiting the counter diffusion of IV group element -- having -- the [in a luminous layer] -- the atomic concentration of IV group element can be maintained from a viewpoint of luminescence reinforcement to the optimal concentration, and the light emitting device of high luminescence reinforcement can be brought about.
[0055] furthermore -- this invention -- the, since it considered as the laminating configuration in which the Lynn-ized boron system semi-conductor layer of the 1st or 2nd conduction type made below into the concentration of the boron (B) atom which occupies the Lynn (P) atom or the Lynn hole which occupies a boron (B) hole for the atomic concentration of IV group element is joined to a luminous layer If effectiveness is taken and spread on bringing about the luminous layer which may be excellent in surface surface smoothness, maintaining the conduction type in an undoping condition, the light emitting device which avoids the complicated nature which dopes an impurity which is therefore different in conduction type, and brings about luminescence of high intensity can be offered simple.

[Translation done.]

* NOTICES *

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damages caused by the use of this translation.

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the mimetic diagram of LED concerning the 1st example of this invention.
[Drawing 2] It is a cross section in alignment with broken-line X-X' of LED shown in drawing 1 .
[Drawing 3] It is drawing showing concentration distribution of the depth direction of the silicon atom in LED concerning the 1st example of this invention.
[Drawing 4] It is the cross section of LED concerning the 2nd example of this invention.
[Description of Notations]
1A, 2A Laminating structure
1B, 2B LED
101 Substrate
102 Buffer Coat
103 1st Lynn-ized Boron System Semi-conductor Layer
104 Luminous Layer
105 2nd Lynn-ized Boron System Semi-conductor Layer
106 Surface Electrode
107 Rear-Face Electrode
108 Twin Crystal

[Translation done.]